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REVISION OF THE SOUTHEASTERN ASIATIC CYPRINID GENUS *OSTEOCHILUS* GUNTHER

by

Ⓒ Jaranthada Karnasuta

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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ABSTRACT

The cyprinid fish genus *Osteochilus* is revised using data obtained from meristic counts, morphometric measurements, and an osteological analysis. Some cladistic techniques were used in erecting a phylogeny but the evolutionary approach was employed in translating the phylogenetic information into a classification. In those species for which specimens were not available (none of which are valid species of *Osteochilus*), data from the literature were carefully evaluated. Fifty-one nominal species have been assigned to *Osteochilus* at one time or another of which 16 species are removed from the genus and three others are of uncertain status and are only provisionally retained in *Osteochilus*. Twenty-one valid species are redescribed. Two new species and one new subspecies are described, making 23 species of *Osteochilus* recognized in this study.

The detailed osteology of *Osteochilus* has been studied for the first time. The study of osteology and oromandibular soft anatomy among labeine genera reaffirms the status of the subfamily Labeinae and the position of *Osteochilus* in it.

Osteochilus is probably derived from a *Labeo*-like ancestor, since the two genera share many common characteristics. The distinguishing features of the genera are regarded as specializations from the more generalized condition in the subfamily. With our present knowledge it is difficult to say which genus, *Labeo* or *Osteochilus*, is the more primitive.

A small ecological study was conducted for three sympatric species in Ubolratana reservoir in northeastern Thailand. Two of the species *O. melanopleura* and *O. lini*, show distinctive habitat selection while the third *O. hasselti*, is generalized. The three species are similar in their food intake but *O. malanopleura* consumes more arthropods.

The center of origin, evolution, and radiation of *Osteochilus* was examined on the basis of the specimens studied and from the literature. The center of abundance of *Osteochilus* species is in the western Borneo and southern Sumatra area, where there are 13 and 12 species, respectively. The occurrence of the same species on the mainland of Southeast Asia and on the islands of Sumatra, Borneo, and Java is probably explained by the fact that these land masses were once connected during the Pleistocene when the

sea level dropped by 100 metres. Some species are unevenly distributed which indicates either that some species have been extirpated regionally because of unfavorable factors, that they arose after the land masses were separated, or that more extensive field collecting activities are needed in order to reveal a more cohesive pattern of distribution. Regrettably, it is still impossible to pinpoint a subregion of southeastern Asia as the center of origin for the genus.

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INTRODUCTION

This study is concerned with the comparative morphology, systematics, and zoogeography of *Osteochilus*, a genus of tropical Oriental fishes belonging to the family Cyprinidae, the world's largest family of vertebrates. Like other members of Cyprinidae they are confined to freshwater. All species of the genus are restricted to southeastern Asia. They extend from southern Burma, eastward to Thailand and Indochina, southward to Malay Peninsula and islands of the Indo-Australian Archipelago within the limits of the Southeast Asiatic continental shelf, and northward to southern China.

Species of *Osteochilus* are mostly small to medium size fishes; the largest species reaches about 50 cm in length while the smallest species is only 6-7 cm long. They are quite common throughout their range, especially in river systems. Many species inhabit mountain streams of tropical rain forests which characterize the tropical island habitats or the mainland habitats not far from the sea. Some river (or lake) lowland species are migratory; they leave the river (or lake) to spawn in paddy fields or flooded areas during the rainy season, a time when these areas are very productive and good hiding places for young fishes. After the breeding season they generally occur in schools when migrating back to the rivers (or lakes). The natural history of the mountain stream species is poorly known.

Osteochilus, along with other freshwater fishes, is used as food by the people of Southeast Asia. Small individuals of this genus and also of other cyprinids are commonly used to make fish sauce which is an important condiment. Two or three species are actively traded as aquarium fishes, with export to Europe and North America.

Fishes of this genus were first studied by Valenciennes in Cuvier and Valenciennes (1842), followed by Bleeker (1852-1863). Both ichthyologists placed the species in the genus *Rohita* Valenciennes (1842). Gunther (1868) recognized and named the genus *Osteochilus* and regarded *Rohita* as a junior synonym of *Labeo* Cuvier (1817). After this time more species were described. Confusion and multiplication of taxa occurred by later ichthyologists, but there has not been a complete revision of the genus since the time of Bleeker (1863) and Gunther (1868).

In order to elucidate the taxonomic status and interrelationships of *Osteochilus* I have conducted a wide ranging morphological study emphasizing osteology and external anatomy to reach the following primary goals:

1. To resolve in so far as possible the systematic problems relating to the genus.
2. To diagnose the included species including providing information on their identification, morphology, variation, size, synonymy, and distribution in Southeast Asia.
3. To attempt to show the position of *Osteochilus* in the classification of the subfamily *Labeinae*.
4. To establish whether or not the genus as now conceived is monophyletic.
5. To determine the relationships of the species using the evaluationary approach to systematics.
6. To study their dispersal and zoogeography.
7. To appraise the hypothesis that the Malay, Sumatra, and Borneo triangle or Sunderland is the center of evolution of *Osteochilus*.

MATERIALS AND METHODS

I. List of Institutions

Facilities and specimens used in this study were provided by the following institutions.

Institutions	Abbreviation
Academy of Natural Sciences of Philadelphia	ANSP
American Museum of Natural History, New York	AMNH
British Museum of Natural History, London	BMNH
California Academy of Sciences, San Francisco	CAS
Field Museum of Natural History, Chicago	FMNH
Museum National d'Histoire Naturelle, Paris	MHNP
Museum of Zoology, The University of Michigan, Ann Arbor	UMMZ
Museum of Zoology, University of Singapore (Raffles Museum Collection)	NMS
Rijksmuseum van Natuurlijke Historie, Leiden	RMNH
United States National Museum of Natural History (Smithsonian Institution), Washington, D.C.	USNM
Zoological Survey of India, Calcutta	ZSI
Zoologisch Museum, Amsterdam	ZMA
National Inland Fisheries Institute Collection, Bangkok, Thailand, (uncatalogued)	NIFI
Kapaus collection of Dr. Tyson R. Roberts (uncatalogued, presently at Tyberon, California)	KCTR

II. Measuring and Counting Methods

Most of the data are original counts of scales, finrays, vertebrae, gill rakers, measurements of body parts, and descriptions of osteological and other morphological features; they were supplemented where necessary from the literature. Cleared and stained specimens, using Taylor's (1967) method, were prepared and studied to assist in studying the problems of relationship.

Measurements were made in a straight line with dial calipers and recorded to the nearest millimeter. Proportions are expressed in thousandths of standard length unless otherwise stated. Most measurements and counts for this study were made following the methods recommended by Hubbs & Lagler (1964), and all are defined below:

Standard length – distance from tip of snout to the posterior edge of hypural plate.

Head length – distance from tip of snout to the posterior edge of opercle. The membranous opercular flap is not included in this measurement.

Eye diameter – distance between anterior and posterior edge of eye ball. In cases where the eye was damaged, measuring the orbit gives a reliable figure.

Snout length –distance from tip of snout, at midline of upper lip, to anterior rim of orbit.

Interorbital space –width at narrowest point between upper membranous rim of each orbit.

Body depth – measured at deepest part of body at origin of dorsal fin.

Predorsal distance – distance between snout tip and origin of dorsal fin.

Preanal distance – same as above except to origin of anal fin.

Prepelvic distance – same as above except to origin of pelvic fin.

Dorsal fin length – base length between first and last ray.

Dorsal fin height – length of fourth (the longest) simple dorsal ray

Pectoral fin length – measured from origin of fin to the tip of longest pectoral ray.

Pelvic fin length – length of first fin ray.

Anal fin height – length from the base to the tip of longest ray.

Length of the caudal peduncle – distance between end of anal base and ventral origin of caudal fin.

Depth of caudal peduncle – depth at the narrowest part of the peduncle, when caudal fin is spread.

Dorsal fin rays– number of branched rays, the last of which may be split at base. In *Osteochilus*, there are four anterior simple rays, of which three are slender and short, and the fourth is strong and the longest. The number of the simple rays is the same in all species.

Pectoral fin rays – total number of branched rays plus the one simple ray.

Pelvic fin rays – total number of branched rays plus the one simple ray. There are nine pelvic fin rays in all species of *Osteochilus*.

Anal fin rays – number of rays in anal fin. There are typically three simple rays and five branched rays in all species of *Osteochilus*. The last branched ray is usually split near the base.

Lateral line scales – number of pored scales on body from the anterior scale in contact with shoulder girdle to hypural plate (the number of scales behind the hypural plate is given in parenthesis).

Predorsal scales – number of scales from first row on nape to origin of dorsal fin. In some species of *Osteochilus*, the predorsal scales are smaller than the body scales, so the number of predorsal scales is counted respectively to the oblique row of body scales.

Circumferential scales – number of scale rows around the body immediately in advance of origin of dorsal fin, stated in a formula giving number above the lateral line on the lateral line, and below the lateral line, e.g., 11/2/13.

Transverse scales – number of transverse scales from the origin of dorsal fin downward to (but excluding) lateral line, and from scale in front of the axillary pelvic scale, or that scale which touches the pelvic fin insertion, upward to (but excluding) lateral line.

Circumpeduncular scales – number of scale rows counted around narrowest part of caudal peduncle.

Number of lateral line scales opposite origin of dorsal fin – number of lateral line scales from first scale behind cleithrum to vertical line from origin of dorsal fin.

Number of lateral line scales opposite the insertion of dorsal fin – same as above except to the vertical line from insertion of last dorsal ray.

Number of lateral line scales opposite origin of pelvic fin – same as above except to vertical line from insertion of pelvic fin.

Number of lateral line scales opposite origin of anal fin – same as above except to vertical line from origin of anal fin.

Number of lateral line scales opposite tip of pectoral fin – same as above except to vertical line from tip of pectoral fin.

Insertion of dorsal fin – the point at the posterior end of the base of dorsal fin.

Number of lateral line scales between the vertical line from insertion of dorsal fin to vertical line from origin of anal fin – in the description a minus figure indicates the number of lateral line scales when the anal fin origin is anterior to the dorsal fin insertion.

Gill rakers – total number of gill rakers on the first gill arch on right side.

III. Systematic Approachs to the Study of Osteochilus Evolution

At the present, there are three current theories of classification as listed below. I employ the evolutionary approach for the study of *Osteochilus*, as I feel it is the most satisfactory method to explain the evolution of this group.

I. **Cladism** (Phylogenetic systematics). Developed by Hennig (1950, 1966), this refers to a taxonomic theory in which organisms are ranked and classified according to their "recency of common descent." Membership of species in taxa is recognized by the joint possession of derived (apomorphic) characters. Grouping and ranking are given simultaneously by the branching points. Phylogeny can, for the purposes of cladistic analysis, be formally expressed in three mutually exclusive hypotheses stated in the following form: taxon A is, by sharing an immediate common ancestor, more closely related to taxon B than it is to taxon C; or A is more closely related to C than it is to B; or C is more closely related to B than it is to A. These competing hypotheses are shown in the following cladograms:

A B C   A C B   A B C

or   or

This scheme, as well as providing a clear statement of alternative phylogenies, avoids the postulation that any of these taxa (A, B, C) is ancestral ie. in the cladogram postulated common ancestors remain hypothetical. In view of the time scale involved, one can not assume that the parental genotype remains unchanged following a split which produces two daughter taxa (sister groups); thus, by convention, parental taxa are considered to have expired after cladogenesis (Mayr, 1969). In the cladistic scheme the relationships and the interrelationships of fossils are determined by exactly the same process as that used for recent taxa (Patterson, 1977; Patterson & Rosen, 1977).

In cladistic analysis, morphological data on homologous structure can be categorized using Hennig's (1966) terminology, viz. as follows:

i)Plesiomorphic.-character state present in the ancestral forms

ii)Apomorphic.-character state present in the derived forms

II. **Evolutionary Systematics** (Synthetics). Organisms are classified and ranked, according to this theory, on the basis of two sets of factors as follows:

i) Phylogenetic branching (recency of common descent, retrospectively defined).

ii) Amount and nature of evolutionary change from the branching point.

The latter factor depends on the rate of evolutionary change that a form undergoes. The evolutionary taxonomist attempts to maximize simultaneously in his classification the information content of both types of variables (i & ii above) (Mayr, 1969,1974).

Evolutionary classification originated with Darwin (1859), who assumed that relationship in the evolutionary sense is determined by both processes of phylogeny, namely, branching and subsequent divergence. The synthetic or evolutionary method of classification thus combines components of cladistics and phenetics. It agrees with cladism in the postulate that as complete as possible a reconstruction of phylogeny must precede the construction of a classification since groups that are not composed of descendants of a common ancestor are artificial and of low predictive value. More generally, it agrees also with cladist in the careful weighting of characters. It rejects, however, the divisional process of classification which is in the cladists definition of "monophyletic". Evolutionary classification agrees with phenetics in the actual, procedure of grouping by a largely phenetic approach. However, in contrast to the unweighting approach of the pheneticis, there is a careful weighting of characters.

III. **Phenetic Systematics** (Numerical Taxonomy). Organisms are classified according to this theory on the basis of overall similarity. Similarity is calculated from presence or absence of numerous unweighted characters or character states (Mayr, 1965; Sneath & Sokal, 1973). This method does not establish groups by inspection, but orders the lowest taxonomic units (species) into groups with the help of standardized procedures.

INTRODUCTION TO THE GENUS *OSTEOCHILUS*

INTRODUCTION TO THE GENUS *OSTEOCHILUS*

Nomenclatural History and Problems

I The Genus.

Gunther (1868) proposed the generic name *Osteochilus* in "Catalogue of Fishes in the British Museum", Vol. 7, p.40, which has been accepted by all subsequent workers.

The type species of the genus, *Osteochilus melanopleura,* was designated by Jordan (1919,p.351) (first species of the genus listed in Gunther 1868).

Diplocheilichthys is an older name than *Osteochilus* but it was used only as a senior synonym by Bleeker (1860, 1863) and treated since then by Gunther (1868) and Weber and de Beaufort (1916) only, as a junior synonym of **Labeo**. Bleeker (1860) proposed the monotypic genus *Diplocheilichthys* for *Lobocheilos pleurotaenia* Bleeker (1855). Having examined the syntypes and many other specimens and the osteology of the species, I believe that it belongs to the genus *Osteochilus*. The name *Diplocheilichthys,* is not associated currently with *Osteochilus* by any ichthyologist while *Osteochilus* is well-known among ichthyologists in Asia, North America, and Europe. Therefore, I intend to appeal to the International Commission of Zoological Nomeclature to retain the name *Osteochilus* as the senior synonym and suppress *Diplocheilichthys.*

Some other species that I place in *Osteochilus* were originally described in other genera (*Rohita,* and *Dangila*) but none is a type species of those genera, consequently, there are no other synonyms for *Osteochilus.*

II The Species.

The systematic study of the freshwater fishes of Southeast Asia started in the early nineteenth century during the period of European colonization. Species of *Osteochilus* were first described by the French ichthyologist Valenciennes (1842) in volume 16 of "Histoire Naturelle des Poissons" by Cuvier and Valenciennes. During 1852-1860 the famous Dutch ichthyologist Dr. P. Bleeker described many new species of *Osteochilus* from the East Indies (Indonesia) and in 1863 published the Atlas which included descriptions (in Latin) and illustrations of all *Osteochilus* that had been described. However, both Valenciennes and Bleeker placed the species under the genus *Rohita* Val. (1842) which also included *Labeo* Cuvier (1817) in part.

Gunther (1868) recognized and named the genus *Osteochilus* and regarded *Rohita* as a junior synonym of *Labeo*. There have been no complete monographs of the genus since Bleeker (1863) and Gunther (1868) ; at that time 14 species were recognized. In 1905, Popta described five more new species from central Borneo. A partial revision was made by Weber and de Beaufort (1916), treating the species of the Indo-Australian archipelago, and they recognized 17 species (including two new species). This is the most important work on the genus following the work of Bleeker and Gunther.

Fowler (1905) described a new species from Borneo, and during 1934-1939 he described eight new species from Thailand (only one is a valid species for *Osteochilus*) and also placed some species of *Rohita* described by Sauvage (1878) in *Osteochilus*. In 1937 he subdivided the genus into two subgenera, *Osteochilus* and *Neorohita*, based only on the size of scales (a character of little or no phylogenetic value). Hora (1934) described a new species from Burma, and in 1942 he proposed two new subgenera, *Osteochilichthys* and *Kantaka*, which consisted of three species of fishes not related to *Osteochilus*; therefore, they should be removed from this genus (this will be discussed in the species account section). Fowler and Hora placed many species of fishes in *Osteochilus* which are now placed in other genera such as *Cirrhinus* and *Labeo*.

Most early fish taxonomists (e.g., Cuvier& Valenciennes, Bleeker, and Sauvage) commonly employed superficial or variable characteristics including certain body proportions. Confusion and multiplication of taxa resulted when later workers (Fowler, Hora, Smith, etc.) described new species based upon specimens that differed only slightly from the description of early workers (i.e. without examining types of earlier workers). For example, Smith (1945) recognized 15 species of *Osteochilus* from Thailand, whereas my study validates the occurrence of only seven.

Diagnosis of *OSTEOCHILUS*

Osteochilus shares many features with other labeine minnows, especially with *Labeo*. Characters that distinguish *Osteochilus* from its relatives are as follows:

1. Upper lip fringed and continuous with the lower lip, forming a sucker-like structure. Lower lip fimbriate or papillate and broadly confluent with isthmus, covering an osseous part of mandible which has a hard, sharp, chisel-like transverse edge.
2. Under surface of upper lip and lateral part of lower lip consisting of several ridge-like costae (plicae), which consist of minute unicellular keratinized projections for which the name unculi has been proposed (Roberts, in press).
3. Dorsal fin moderately long, without a spinous simple ray, and with 10-18 branched rays (generally 8-9 in Barbinae, 10-12 in *Labeo*, 8-14 in *Cirrhinus*, 8-12 in *Epalzeorhynchos*, and more than 20 in *Labiobarbus)*.

Description of *OSTEOCHILUS*

Body oblong or subcylindrical and compressed. Snout conical, more or less prominent, and tubercles, if present, one to three or numereous on the anterior portion. Mouth terminal, subinferior, or conspicuously inferior and horseshoe-shaped. Skin of rostrum (rostral fold) extended, partially covering the front part of upper lip. Upper jaw curved and protrusible. The upper lip and lower lip well developed, fringed, and continuous, and forming a sucker-like structure; both jaws covered with keratinized callus sheath. Lower lip fimbriated or papillated at outer part and broadly confluent with isthmus, covering the osseous part of mandible which has a hard, sharp, chisel-like transverse edge. Ventral surface of upper lip and inner part of lower lip consisting of several ridge-like costae (plicae), which consist of a number of taste buds and minute unicellular keratinized projections called unculi. The series of unculiferous folds or costae are long and unbroken distally in some species. and divided into two, three or more mound-shape portions in other species. Two pairs of barbels, rostral and maxillary, the rostral pair usually about one half the length of the maxillary pair. Gill membranes broadly united to the isthmus about opposite hind border of preopercle. Pharyngeal teeth in three rows, 2.4.5 - 5.4.2. Scales generally large (lateral line scales 27-35), but small in two species (lateral line scales 45-53), longtitudinal or radially striated. Lateral line complete, extending to the middle of the caudal peduncle, sensory tubes simple. Dorsal fin iv, 10-18; the fourth simple ray is nonosseous and smooth on its posterior edge, consistently with 10-18 branched rays. Dorsal fin with basal scaly sheath, its origin generally slightly before the insertion of pelvic fins and ending before, above, or behind origin of anal fin. Pelvic fin with one simple ray and eight branched rays giving a formula of P2 = 9. The pectoral fin has one simple ray and 13-16 branched rays giving a pectoral fin formula of P1 = 14-17. The anal fin consistently has three simple rays which are moderately or rather weak, and five branched rays giving an anal fin formula of A-iii, 5. Caudal fin deeply forked, with equal lobes or upper lobe longer.

Distribution

Fish of the genus *Osteochilus* are restricted to Southeastern Asia. They extend from southern Burma, eastward to Thailand and Indochina, southward to Malay Peninsula and islands of Indo-Australian Archipelago within the limits of the southeast Asiatic continental shelf.

In southern Burma there is only one species, *O. hasselti*. In central Thailand there are four lowland species present (*O. melanopleura*, *O. hasselti*, *O. schlegeli*, and *O. microcephalus*) and one forest stream species (*O. waandersi*) restricted to the southeastern part. There are four lowland species present in the Mekong basin, the main river of Indochina (*O. melanopleura*, *O. hasselti*; *O. microcephalus*, and *O.lini*). *O. lini* is restricted to lower Mekong tributaries. Along the coastline of Vietnam and southern China, including Hainan Island, there are only two species and both are endemic to that area: *O. brachynotoperoides* is found in the middle part of Vietnam, and *O. salsburyi* is in north Vietnam, southern China, and Hainan. In the southern part of continental Southeast Asia, in the Malay Peninsula, there are seven species present (*O. melanopleura*, *O. hasselti*, *O. microcephalus*, *O. enneaporus*, *O. waandersi*, *O. spilurus*, and *O. kahajanensis*). This is close to the center of diversity which is between Sumatra and Borneo. There are 12 species in Sumatra; the most diverse area is in the southern part where there are the following 12 species: *O. melanopleura*, *O. hasselti*, *O. microcephalus*, *O. enneaporus*, *O. waandersi*, *O. spirulus*, *O. pleurotaenia*, *O. triporus*, *O. intermedius*, *O. kahajnensis*, *O. schlegeli*, and *O. borneensis*. Similarly, in western Borneo the Kapuas River with 13 species is the most diverse area on the island; there is the same fauna as in southeast Sumatra except that *O. kappeni* is endemic to the Kapuas. The northwestern part of Borneo (Sarawak) is separated from central Borneo by a mountain range; there are four species: *O. hasselti*, *O. microcephalus*, *O. kahajenensis*, and *O. sarawakensis* (the last species is endemic to mountain streams of Sarawak). In eastern Borneo the Mahakam is the most important drainage. It has been isolated from the western drainage for a long time but they share some species such as *O. schlegeli*, *O. pleurotaenia*, and *O. enneporus*, and there are two endemic species, *O. kalabua* and *O. bellus*. Eastern Borneo is a very difficult area to collect in and only a few collections exist so we have a very poor knowledge of the number of species. In northeastern Borneo (Malaysian North Borneo), the area most isolated from the rest of the fauna, only two species are present and one is endemic to the area (*O. ingeri* and *O. kahajanensis*; *O. kahajanensis* has a shorter dorsal fin here than in other areas, and is recognized as a new subspecies, *O. kahajanensis chini*, in this study). The southern part of Borneo and Java share the same fauna because they shared the same drainage during the Pleistocene. There are seven species of *Osteochilus* present: *O. melanopleura*, *O. hasselti*, *O. microcephalus*, *O. pleurotaenia*, *O. kahajanensis*, *O. spirulus*, and *O. waandersi*. Only one species, *O.hasselti*, is reported from Bali which is at the southeastern end of the range of the genus. Of all the species *O. hasselti* and *O. microcephalus* have the largest range (see fig.3).

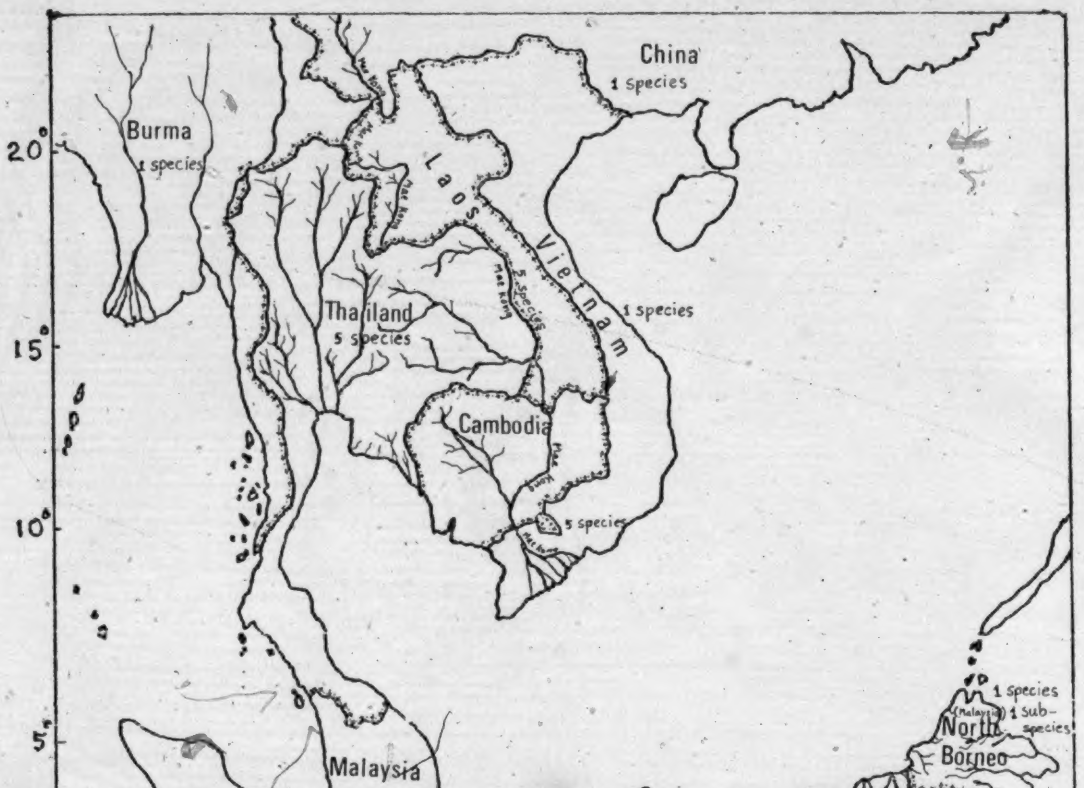
China
1 species
Burma
1 species
Laos
Mae Kong
Vietnam
1 species
5 species
Thailand
5 species
Cambodia
5 species
Malaysia
7 species
Sumatra
12 species
INDONESIA
1 species
(Malaysia)
1 Sub-species
North Borneo
5 species
(Malaysia)
Sarawak
6 Species
Kapuas
13 species
Borneo
Mahakam
7 species
Wallace's line
7 Species
Java
1 Species
Bali
20°
15°
10°
5°
0°
5°
10°
95°
100°
105°
110°
115°

Fig. 1 Distribution of the genus Osteochilus

Remarks

The original description of *Osteochilus* given by Gunther 1868, p.40 is as follows:

> "Scales rather large. Dorsal fin without osseous ray, with from thirteen to twenty one rays, commencing in advance of the ventrals. Snout obtusely rounded, maxillary region scarcely thickened, and but slightly projecting beyond the mouth. Mouth transverse, inferior or subinferior, with the lips more or less thickened, fringed or crenulated, instead of inner fold, as described in *Labeo*, the osseous part of the mandible forms a hard sharp transverse prominence, no symphysial tubercle. Barbels small, nearly always four. Anal scales not enlarged. Anal fin very short. Pharygeal teeth 5.4.2-2.4.5. Snout sometimes with horny tubercles which periodically fall off leaving their former bases as shallow round depressions (pores)."

This old description, which lacks an accompanying illustration, is not diagnostic for the genus. Similar descriptions have been given to other related genera, especially to *Labeo*, and this has caused much difficulty in distinguishing these genera. Confusion of taxa resulted when later workers described new species and placed them incorrectly in various genera. Weber & de Beaufort (1916) illustrated the mouth structure of *Osteochilus*, but their detailed description could still apply to species of other genera. I will try to clarify this problem by doing a detailed study of the oromandibular structures, which include the major characters used to separate labeine genera, in order to present a diagnosis for the genera and to study the interrelationships among the genera. The details of the study of this organ will be presented and discussed in a later section.

SPECIES ACCOUNTS OF *OSTEOCHILUS*

SPECIES ACCOUNTS OF *OSTEOCHILUS*

Key to the Species of Osteochilus

1.a. lateral line scales 45-53 2

1.b. lateral line scales 27-35 3

2.a. mouth ascending; large blackish vertical blotch on each side of body above pectoral fin; snout entire; l.l. 45-53; D. IV,17-18; c.f. 22-23/2/23-24; c.p. 22-24; g.r. 27-35 (may reach 40 cm in very large specimens); (wide distribution ,Thailand, Maekong basin, Malay Peninsula, Indonesia) .... *O. melanopleura* (Bleeker)

2.b. mouth normal (subinferior); no large blacklish blotch above pectoral fin; snout with three tubercles; l.l. 47-49; D. IV,16-18; c.f. 17/1/17; c.p. 22; g.r. 20-25 (Sumatra, Borneo; uncommon) .... *O. borneensis* (Bleeker)

3.a. circumpeduncular scales 22; c.f. 16-17/2/16-17; predorsal scales 13-14; mouth ascending; large blackish blotch above pectoral fin; l.l. 34-35; D. IV,16; snout entire; g.r. 29-34 (central Borneo; Mahakam tributaries; three specimens known) .... *O. kalabau* Popta

3.b. circumpeduncular scales 12-20; c.f. 9-13/2/11-15; predorsal scales 8-11 4

4.a. circumpenduncular scales 20; l.l. 32-33; D. IV,13-14; c.f. 13/2/15; predorsal scales 10-11; snout entire; g.r. 25-35 (wide distribution, Sumatra, Borneo, Malaysia, central Thailand, uncommon) .... *O. schegeli*

4.b. circumferential scales 12-16 5

5.a. circumpeduncular scales 12; c.f. 9/2/11; l.l. 30; five longitudinal stripes along side of body; snout entire (southern Borneo, one specimen known) .... *pentalineatus* Kottalat

5.b. circumpeduncular scales 16 6

6.a. lateral line scales 27–29; D. IV,10–11; c.f. 9/2/11; predorsal scales 9–10; snout entire; size small, not more than 70 mm; g.r. 28–30; (Sumatra, Borneo, Malaysia; common .... *O. spilurus* (Bleeker)

6.b. lateral line scales 30–34 7

7.a. main part of body plain,with or without blotch on the scales above pectoral fin, usually with a large round black spot on caudal peduncle 8

7.b. body with pattern of spots, rows of spots, or stripes 13

8.a. three tubercles on snout, branched dorsal rays 16; l.l. 32; c.f. 12/2/14 (River Bo, central Borneo, one specimen known) .... *O. repang* (Popta)

8.b. no tubercles on snout (if present, small and numerous 9

9.a. c.f. 9/2/11 body long and slender; snout entire; l.l. 33–34, branched dorsal rays 10 (Lake Kontum, middle Vietnam, probably endemic to the lake; one specimen known) .... *O. brachynoptereroides* Chevey

9.b. c.f. 11–13/2/13–15 10

10.a. c.f. 13/2/15 body deep and compressed, snout entire; two small black bars on the scales above pectoral fin, one above and one below lateral line usually present in young (many specimens of this species with rows of spots on the body, see no.22b; (central Borneo, Kapuas River; uncommon) .... *O. kappeni* (Bleeker)

10. b. c.f. 11/2/13 11

11.a. branched dorsal rays 10; body long and slender; snout may have some small numerous tubercles or pores; mouth conspicuously inferior; lips greatly expanded g.r. 38-53 (young specimen of this species has median stripes, see no.17a; (Sumatra, Java, Borneo; uncommon)
.... *O. pleurotaenia* (Bleeker)

11.b. branched dorsal rays 10-14 (rarely 15); body oblong; snout entire; mouth subinferior, lips normal, g.r. 27-35.. 12

12.a. branched dorsal rays 10-12; l.l. 30-32; longitudinal median lateral stripe may be present in young specimens (see no.19.b) (Southern China, North Vietnam, Hainan Island; common).. *O. salsburyi* Nichole & Pope

12.b. branched dorsal rays 13-14 (rarely 15); l.l 32-33; two spots on the scales on the side above pectoral fin, one above and one below lateral line (eastern Thailand, lower Mekong Basin; common).. *O. lini* Fowler

13.a. body with a median longitudinal lateral stripe, and no spots 16

13.b. body with pattern of spots or rows of spots or stripes (more than one); with or without tubercle on snout.. 20

13.c. body with both a median longitudinal stripe and rows of spots on the body.............. 14

14.a. median lateral stripe thick and distinct, branched dorsal rays 10-12 usually with one or three or several small tubercles on snout.. 15

14.b. branched dorsal rays 11-13; snout entire; about 5-8 (5-6 distinct) rows of spots on the body, the row of spots on the lateral line more intense than others and forming a thin median lateral strip; mouth conspicuously inferior; l.l. 32-33 (this species may lack a median lateral stripe, (see no.26b) (Sarawak, and western North Borneo, common) .... *O. sarawakensis* new species.

15.a. g.r. 44-45; c.f. 9/2/11; mouth conspicuously inferior; usually with three tubercles

on snout but some specimens may have several additional small tubercles; median lateral stripe is distinct on posterior half of body; about 4 rows of spots on the body, 2 above and 2 below the median lateral stripe, and also distinct on posterior half of the body; general color of body very dark. (Some specimens of this species without median lateral stripe, see no.26a) (River Bo in central Borneo; six specimens known)
.... *O. bellus* Popta

15.b. g.r. 27–35; c.f. 11/2/13; mouth subinferior; usually with one or three tubercles on snout (rarely without tubercles); median lateral stripe extending from gill opening to the end of caudal peduncle; rows of spots irregular, not distinct, (majority of specimens without rows of spots, see no.19a) (wide distribution; Thailand, Indochina, Malaysia, and Indonesia; common)
.... *O. microcephalus* (Cuv.&Val.)

16.a. g.r. 40–60 in adult fish; mouth conspicuously inferior 17

16.b. g.r. 27–35 in adult fish; mouth subinferior........................ 19

17.a. branched dorsal rays 10–11; snout with small numerous tubercles or entire; l.l. 30–32; (median lateral stripe may be absent in adult specimens of this species, see no.11.a.) (Sumatra, Java, and Borneo; uncommon)
.... *O. pleurotaenia* (Bleeker)

17.b. branched dorsal rays 11–13; snout with one or three tubercles; l.l. 31–33
.... 18

18.a. median lateral stripe extends from gill opening (some specimens from posterior border of eye) to the end of caudal fin rays; lower part of the body with very light color, snout rather pointed (Sumatra, Borneo, Malay Peninsular, southeastern Thailand; common) .... *O. waandersi* (Bleeker)

18.b. median lateral stripe extending from gill opening to the end of caudal peduncle;

general color very dark; snout blunt (Sumatra, Borneo, Malay Peninsular; common in Kapuas)

....*O. enneaporos* (Bleeker)

19.a. one or three tubercles on the snout, median lateral stripe extending from gill opening to the end of caudal peduncle (this species may have rows of spots on the body, see no. 15b) (wide distribution; Thailand, Indochina, Malaysia, and Indonesia; common)

.. ..*O. microcephalus* (cuv.&val.)

19.b. snout entire; median lateral stripe present only in young specimens (see no. 12a.) (southern China, northern Vietnam and Hainan Island; common)

....*O. salsburyi* Nichole & Pope

20.a. branched dorsal rays 15–18; snout entire...21

20.b. branched dorsal rays 10–13; snout with or without tubercles...23

21.a. branched dorsal rays 15–16, body with 9–10 longitudinal lateral stripes; each costa on the ventral part of upper lip long and undivided. (Baram River, Sarawak 4th Division, two specimens known) ....*O. harrisoni* Fowler

21.b. branched dorsal rays 15–18 (rarely 12–14); body with 6–8 rows of spots on posterior two-thirds of the body; each costa on the ventral part of upper lip short and divided into two or three portions..22

22.a. c.f. 11/2/13; rows of spots quite distinct, sometimes forming stripes on posterior half of body;fresh specimens with orange spots on body (wide distribution, from Burma to Indochina and Indonesia; common)

....*O. hasselti* (Cuv. & Val.)

22.b. c.f. 13/2/15; rows of spots less distinct, body deep and compressed (rows of spots may disappear in this species, see no. 10a) (Kapuas River, Borneo, uncommon)

.. .. *O. kappeni* (Bleeker)

23.a. a large black spot on anterior portion of dorsal fin 24
23.b. without black spot on anterior porton of dorsal fin 25

24.a. one to three tubercles on snout; each costa on upper lip divided into two or three portions, g.r. 28–31; branched dorsal rays 11–12; c.f. 11/2/11–13; dorsal fin usually falcate (Sumatra, Borneo; common in Kapuas River)
.... *O. triporus* (Bleeker)

24.b. no tubercles on snout; costae on upper lip long, undivided; g.r. 37–50; branched dorsal rays 13–14; c.f. 9/2/13; dorsal fin normal (Sumatra, Borneo; uncommon)
.... *O. intermedius* Weber & de Beaufort

25.a. body marked by small bar on each scale pocket forming a reticulated pattern on the body, c.f. 9/2/11 (rarely 10–11/2/11); l.l. 30–31; g.r. 40–45; branched dorsal rays 11–12 (eastern North Borneo; common)
.... *O. ingeri* new species

25.b. body marked by rows of spots which are usually distinct on the posterior half of the body 26

26.a. c.f. 9/2/11; g.r. 44–45; branched dorsal rays 10–11; three tubercles on snout (some specimen with several small tubercles); l.l. 30–31 (this species may have a median lateral band, see no. 15a.) (central Borneo, River Bo, six specimens known)
.... *O. bellus* Popta

26.b. c.f. 11/2/13; g.r. 26–34; branched dorsal rays 11–13; l.l. 32–33; snout entire (this species may have very thin median lateral stripe, see no. 14b) (Sarawak, western North Borneo, common)
.... *O. sarawakensis* new species

SPECIES DESCRIPTIONS OF *OSTEOCHILUS*

23 SPECIES

SPECIES DESCRIPTIONS OF *OSTEOCHILUS*

The genus *Osteochilus*, as now concieved, has 23 species with one species divided into two subspecies. The genus is divided into seven species group, based on relationships, as follows:

O. microcephalus group, with two other species; *O. salsburyi* and *O. brachynotopteroides*

O. waandersi group, with three other species: *O. enneaporus, O. bellus,*and *O.pleurotaenia*

O. kahajanensis group, consists of one species and two subspecies: *O. kahajanensis kahajanensis* and *O. kahajanensis chini*

O. spilurus group with one other species: *O. ingeri*

O. triporus group with four other species: *O. intermedius, O. sarawakensis, O. harrisoni*, and *O. pentalineatus*

O. hasselti group with four other species: *O. kappeni, O. lini, O. repang*, and *O. borneensis*

O. melanopleura group with two other species: *O. kalabau*, and *O. schlegeli*

Osteochilus microcephalus (Valeciennes)

Rohita microcephalus Valenciennes in Cuvier and Valenciennes, 1842: Vol. 16, p.275; original description; type locality: Bantam River, Java; Syntypes dry, mounted, 2 spec.) RMNH 2115, 2116; 7 inches total length (given by Valenciennes), 150.8 mm and 151.7 mm standard length (my measurement).

Rohita (Rohita) microcephalus Bleeker, 1860; Vol.2, p.173; description; locality: Java (Tjikao), Sumatra (Lahat). ----1863: Vol.3, p.66; description with color plate.

Rohita (Rohita) vittata Bleeker, 1860; Vol. 2, p.178; description; locality: Java (Batavia, Lebak, Buitenzorg, Tjikao, Parongkalong, Surabaya, Gempol), Sumatra (Pangabuang, Padang, Solok, Meninju, Lahat), Borneo (Bandjermassin, Pengaron, Pontianak). ----1863: Vol 3, p.68; description with color plate

Rohita brachynotopterus Bleeker, 1855: p.266; original description; type locality: Sumatra (Lahat); holotype BMNH 1866.5.2.171, 90 mm total length (given by Bleeker), 66.6 mm standard length (my measurement)

Rohita (Rohita) brachynotopterus Bleeker, 1860: Vol.2, p. 122; description. ----1863: Vol.3, p.67; description with color plate.

Osteochilus microcephalus Gunther, 1868: Vol.7, p.43; description (from Bleeker's specimen).

Osteochilus vittatus Gunther, 1863 (in part): Vol.7, p.44; description (from Bleeker's specimen).

Osteochilus brachynotopterus Gunther, 1868: Vol. 7, p.43; description (from Bleeker's specimen)

Osteochilus vittatus Weber and de Beaufort, 1916 (in part): Vol.3, p.131; description; locality: Sumatra (Djambi, Gunung Sahilan, Palembang), Borneo (Kapuas at Pontianak).

Osteochilus brachynotopterus Weber and de Beaufort, 1916: Vol.3, p.134; description; locality: Sumatra (Taluk, Si-Djanjung).

Osteochilus vittatus Smith, 1945 (in part): P. 216; diagnosis; locality: Chao Phya River, Thailand.

Nomenclature

Valenciennes (Valenciennes, 1842) described *O. microcephalus* from 2 dry individuals of about the same size. Valenciennes did not indicate the presence of the median lateral stripe or of any coloration in his original description (which presumably had disappeared in the dry, mounted, and vanished specimens). For this reason the specimens look similar to the type specimens of *O. hasselti* which are also dry specimens (type specimens of *O. hasselti* have a short dorsal fin which is similar to *O. microcephalus*). This fact is indicated by Valenciennes in the beginning of the original description: "I think I should place this specimen following the previous one because it resembles in form but the head is smaller, the dorsal fin taller, forked, and shorter" (translated from French). This is probably the reason why Weber & de Beaufort (1916) placed *O. microcephalus* as a junior synonym of *O. hasselti*. *O. microcephalus* may or may not have tubercles on the snout. Bleeker, Gunther, and Weber and de Beaufort used this variable character to separate the species. They recognized *O.vittatus* (non Cuv. & Val.) as a tuberculate form, and *O. microcephalus* and *O. brachynotopterus* as a non-tuberculate form. Bleeker did not see the type specimen of *O. vittatus* and used the original description. Valenciennes's original description is too superficial to diagnose the species and he called *O. vittatus* as "Le Rohite a bandes" (=striped Rohite), (see discussion on *O. vittatus* page 185). Bleeker mistook *O. microcephalus* to be *O. vittatus* but still recognized *O. microcephalus* as the non-tuberculate species. Bleeker (1855) described *O. brachynotopterus* from a specimen with 10 branched dorsal rays (*O. microcephalus* usually has 11-13 branched dorsal rays and all Bleeker's specimens of *O. microcephalus* have 13 branched dorsal rays). The type specimens of *O. microcephalus* that I examined have three distinct tubercles at the front of the snout and other characteristics agree with what many ichthyologists recognized as *O. vittatus*.

Valenciennes's type specimen of *O. vittatus* has 14 branched rays and it was indicated by Valenciennes that it has 9 brown stripes. For this reason I believe that Bleeker's *O. vittatus* is not conspecific with Valenciennes's species and therefore, I regard Bleeker's *O. vittatus* as a junior synonyme of *O. microcephalus*. Many specimens of this species which I examined have 10 branched dorsal rays; therefore, I also consider *O. brachynotopteus* to be a junior synonym of *O. microcephalus*

Diagnosis

D. IV, 10–13; l.l. 32–33; c.f. 11/2/13; c.p. 16; g.r. 27–35

O. microcephalus usually has one or three or no tubercles on the snout and a median longitudinal stripe extending from the gill opening to the end of the caudal peduncle.

O.microcephalus shares some characters with *O. waandersi* and *O. enneaporus* such as a median longitudinal stripe and tubercles on the snout. The latter two species have high gill raker counts (40–60), but *O. microcephalus* has only 27–35 gill rakers. The mouth is subinferior in *O. microcephalus* but conspicuously inferior in *O. waandersi* and *O. enneaporus*, and also the latter two species have a more slender body.

Description

Body oblong, slightly compressed, depth 276–370 (mean=345) (in thousandths of standard length). Head 210–240 (mean=225); eye 48–65 (mean=56). Snout 73–88 (mean=81), with three tubercles in the front (may be one tubercle or none), the middle one the largest and lateral one small or rudimentary; snout longer than eye diameter, shorter than interorbital space, about equal to the postorbital part of the head. Interorbital space convex 107–128 (mean=119). Mouth subinferior, two pairs of well developed barbels; maxillary barbels about equal to eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed, moderately long, undivided costae. Predorsal length 406–479 (mean=439); origin of dorsal fin opposite 9th–10th scale of lateral line before mid-point between tip of snout and caudal base and also before pelvic fin insertion. Dorsal fin short but variable in height, last simple dorsal ray variably produced, 268–439 (mean=292), and the base of dorsal fin 274–305 (mean=292); the insertion of the dorsal fin opposite 20th–22nd scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from one to two. Tip of pectoral fin not reaching pelvic fin insertion, opposite 9th–20th scale of lateral line. Prepelvic length 485–524 (mean=498); pelvic fin insertion opposite 11th–12th scale of lateral line. Preanal length 751–816 (mean=763), anal fin concave, third simple ray rather weak; anal fin origin opposite 21st–23rd scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 149–187 (mean=165); least depth of caudal peduncle 119–146 (mean=135), less than half of head length, and surrounded by 16 scales rows. Scales with nearly parallel longitudinal radii, predorsal scales 10; circumferential scale 11/2/13; transverse scales (to the base of pelvic fin) 5.5/1/4.5. Lateral line scales 31–34, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 27–35 (may reach 40 in specimens over 130 mm long S.L.)

Preserved specimens are dusky on the upper two-fifths of the side; the dorsal part of head and back are darker than the rest of the body. A median lateral stripe extends from the gill opening to the end of the caudal peduncle, which may become more or less defined as the fish enters different kinds of environments (as observed in aquarium specimens), and may disappear when the fish dies. Live specimens are greyish-silver with pink or red fins, dorsal and caudal fins with melanin pigment on the membrane.

Distribution

O. microcephalus is one of the most common species of *Osteochilus* and has a wide distribution: northern Thailand extending south through the Peninsula, Sumatra, Java, and Borneo. It also common in northeastern parts of Thailand, Mekong Basin, Laos, and

Cambodia and probably S.Vietnam.

Habitat

O. microcephalus occurs in a wide variety of habitats but it is usually found at low elevations in large turbid rivers. The rapid parts of rivers preferred.

Material examined

(276 specimens 50.0–140.0 mm standard length)

Syntypes: RMNH 2115 (150.8 mm) Bantam River, Java
RMNH 2116 (151.7 mm) Same data

Other specimen:
BMNH 1866.5.2.171 (166.6 mm, type of
O. brachynotopterus Sumatra (Lahat)

Borneo: BMNH 1892.10.7.27 (1 spec.) Baram River, Sarawak
FMNH 62998 (1 spec.) Niah River, Sarawak, 4th Div.
FMNH 68847 (1 spce.) Sungai Tangap, Sarawak, 4th Div.
FMNH 68849 (1 spec.) Sungai, Subis, Sarawak, 4th Div.
FMNH 69877 (2 spec.) Sakaloh, Niah, Sarawak
FMNH 63000 (1 spec.) Niah R. at Pk. Lobang, Sarawak
4th Div.
FMNH 68703 (1 spec.) Sungai Subis, Sarawak 4th Div.
FMNH 68846 (2 spec.) Sokakaloh, Niah, Sarawak.
4th Div.
FMNH 68848 (1 spec.) Niah, Sarawak, 4th Div.
MHNP 85-177-44-9 (2 spec.) no specific locality
KCTR 76-16 (3 spec.) Sungai Tekam, small forest
streams where it enters the right side of the

Kapuas main stream about two km upstream from Sanggau

KCTR 76-27 (2 spec.) Rocky channel in mainstream of Sungai Pinoh, 37 km S. of Nangapinoh

KCTR 76-29 (3 spec.) Rocky channel in main stream of Sungai Pinoh at Nanga Saian, 45 km south of Nanggapinoh

KCTR 76-31 (5 spec.) Bar in mouth of Sungai Malawi at Sintang

KCTR 76-37 (8 spec.) Small forested stream, where it flows into Sungai Mandai, 2-3 km upstream from its confluence with Kapuas mainstream

RMNH 233688 (1 spec.) Bandjermassin

RMNH 7963 (3 spec.) Sintang

ZMA 116.070 (1 spec.) no specific locality

ZMA 116.072 (1 spec.) Sintang

ZMA 116.073 (5 spec.) Poetoes Sibau

Indochina: MHNP 85-177-44-13 (1 spec.) Annam (Vietnam)

MHNP 85-177-44-12 (1 spec.) Tonkin

MHNP 85-177-5-1 (1 spec.) Cochinchina

UMMZ 181152 (1 spec.) Tributary from east Tonle Sap River, 15 km NW of Pnhom Penh, Cambodia

Malaysia (continental):

BMNH 1922.5.19.64-66 (3 spec.) Tahan River

NMS 1894 (1 spec.) Sadili River, Johore

NMS 620 (1 spec.) Ulu Jelei, Pahang

NMS 623 (1 spec.) Kuala Tahan, Pahang

NMS 624 (2 spec.) Kuala Tahan, Pahang

NMS 1897 (2 spec.) no specific locality

(mixed with two spec. of *O. waandersi*

Sumatra: AMNH 9505 (1 spec.) Djambi

RMNH 5011 (2 spec.) Sockadana

RMNH 26910 (3 spec.) Sockadana

UMMZ 155575 (3 spec.) Singkarak

UMMZ 155576 (1 spec.) Moesi River, Palembang

ZMA 116.090 (2 spec.) Talock

ZMA 116.089 (1 spec.) Sidjoengdjoeng

ZMA 116.091 (1 spec.) no specific locality

ZMA 116.097 (16 spec.) Batang Hari River at Djambi

ZMA 116.064 (1 spec.) Gunung Sahilan

ZMA 116.066 (2 spec.) Palembang

ZMA 116.065 (1 spec.) Palembang

Thailand: ANSP 58046-48 (3 spec.) Chiengmai

ANSP 58051 (1 spec.) Chiengmai

ANSP 58049 (1 spec.) Chiengmai

ANSP 97249 (2 spec.) Kemarat

ANSP 87249 (5 spec.) Bangkok

FMNH 50812 (3 spec.) Kam Pang Pet

MHNP 85-177-44-4 (2 spec.) no specific locality

NMNH 108055 (1 spec.) Bangkok

NMNH 108044 (1 spec.) Chao Phya River at Bangsai

NMS 687 (1 spec.) Chong Mek, Pibulmangsaharn, Ubol

UMMZ 201082 (1 spec.) Mun River at Ban Dan, Ubol

UMMZ 201084 (1 spec.) Mun River at Ban Dan, Ubol

UMMZ 201089 (4 spec.) Mun River 13 km downstream from Ubol

UMMZ 201090 (2 spec.) Huay Kwang, o.3 km from Mun River

UMMZ 201088 (1 spec.) Mun River, 1 km upstream from Ubol

UMMZ 201081 (1 spec.) Creek at Ban Tha Mai, Ubol

UMMZ 201087 (6 spec.) Huay Phai, Ubol

UMMZ 201085 (1 spec.) Mun River at Ban Dan, Ubol

UMMZ 201083 (1 spec.) North shore of Mun River at Ubol

UMMZ 192984 (1 spec.) Nam Pong River at Nongwai

UMMZ 195467 (5 spec.) Mekong River, 10 km upstream from Nong Khai

UMMZ 19275 (6 spec.) Meklong River at Rajburi

UMMZ 195678 (12 spec.) Market at Ubol

UMMZ 195865 (1 spec.) Meklong River at Ban Pong

UMMZ 195603 (1 spec.) Mekong River, 6 km upstream from Nakorn Panom

UMMZ 195096 (1 spec.) Chao Phya River, flood water 20 km north of Nakorn Sawan

UMMZ 195712 (7 spec.) Mun River, 5 km downstream from Ubol

NIFI (uncatalogued, 3 spec.) Cheingmai

NIFI (uncatalogued, 14 spec.) Mekong River at Nong Khai

NIFI (uncatalogued, 24 spec.) Mun River at Ubol

NIFI (uncatalogued, 18 spec.) Sri Sawat, Kwai Yai River

NIFI (uncatalogued, 15 spec.) Pattani River at Yala

NIFI (uncatalogued, 17 spec.) Meklong River at Rajburi

NIFI (uncatalogued, 14 spec.) Chao Phya River at Nakorn sawan

NIFI (uncatalogued, 5 spec.) Chao Phya River at Ayuthya

Table 1 Proportional measurements of *O. microcephalus* (measurements expressed as thousandth of standard length)

Characters	type	other specimens	
		mean	S.D.(n=274)
Depth	365	350	23.7
Head	219	225	15.2
Eye	48	56	7.5
Snout	86	81	5.8
Interorbital space	124	119	10.2
Base of dorsal fin	334	289	15.4
Fourth simple dorsal ray	284	292	28.9
Predorsal length	422	439	20.4
Prepelvic length	501	498	22.8
Preanal length	756	763	12.8
Third simple anal ray	245	219	10.8
Pectoral fin length	243	219	9.9
Pelvic fin length	222	222	11.8
Depth of caudal peduncle	135	135	7.9
Length of caudal peduncle	114	164	12.7
Lateral line scales	32	32.5	0.8
Predorsal scales	10	10.2	0.7
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	13	11.9	0.5
Pectoral rays	16	14.8	0.4
Gill rakers	38	30.0	6.2
Maxillary barbel	90	58	7.2
Rostral barbel	41	32	7.5

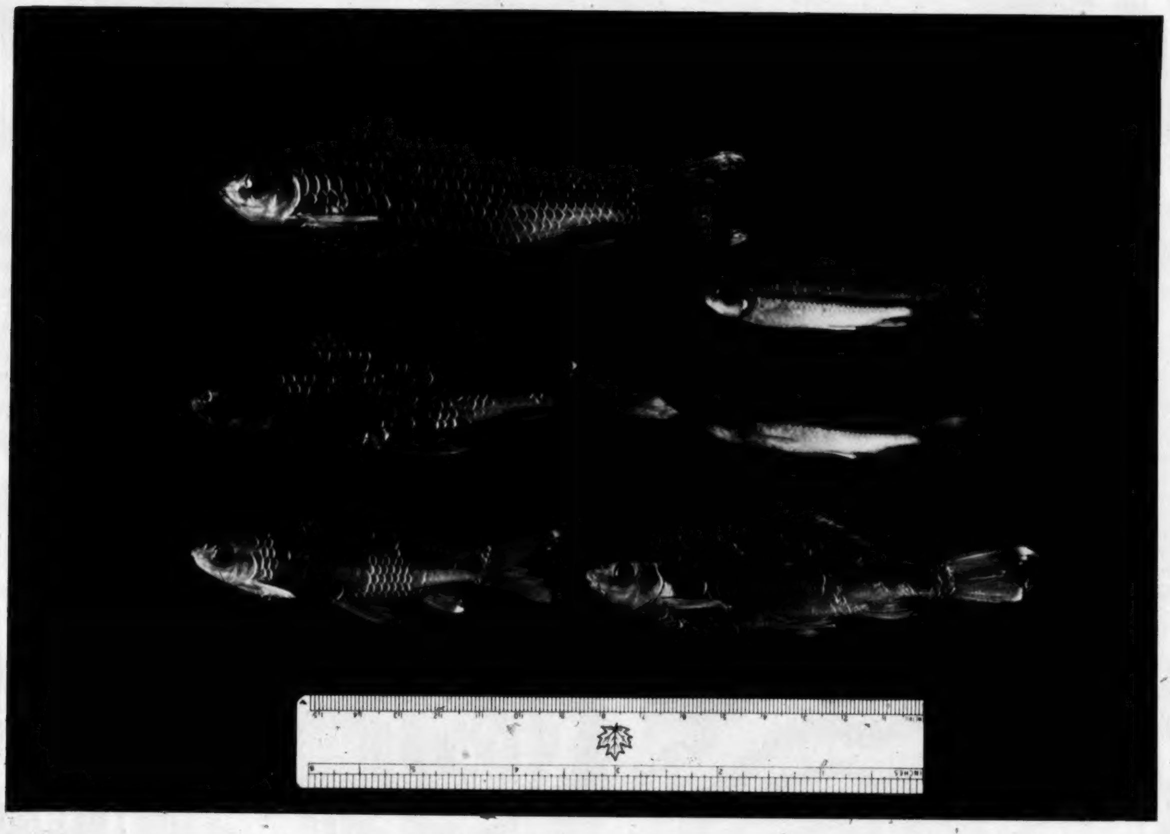

Fig. 2 *Osteochilus microcephalus* (Valenciennes), clockwise from top NIFI uncatalogued (Nongkai), NIFI uncatalogued (Payao), NIFI uncatalogued (Chao Phya River), KCTR 76-31, KCTR 76-27.

Osteochilus salsburyi Nichols and Pope

Osteochilus salsburyi Nichols and Pope, 1927: p 348, fig 18; original dscription; type locality: Nodoa, Hainan; holotype AMNH 8371, 85mm standard length (given by Nichols and Pope), 83.7 mm (my measurement).

Osteochilus baramense Koller, 1927: p 30; Hainan; (not seen)

Osteochilus salsburyi Nichols and Pope, 1943: p67, fig. description; locality: Kwangtung and Hainan.

Nomenclature

Osteochilus salsburyi was described by Nichole and Pope in 1927, and *Osteochilus baramense* was described by Koller in the same year, the specimens also from Hainan. Nichols and Pope (1943) considered Koller's species to be a junior synonym of *O. salsburyi*. I have not seen either type specimen nor the publication of Koller (1927), but I agree with Nichols and Pope that there is only one species of *Osteochilus* on Hainan Island.

Diagnosis

D. IV,11 (rarely 10); l.l. 30-32; c.f. 11/2/13; c.p. 16

Osteochilus salsburyi has no tubercles on the snout, and has a short dorsal fin (usually 11 branched rays). A median lateral stripe is usually present in young specimens and traces of it can be seen in some adults on the posterior part of the body.

O. salsburyi is very similar to *O. microcephalus*, but the latter species has one or three tubercles on the snout, and a distinct median lateral stripe extends from the head to the end of the caudal peduncle.

Description

Body oblong, and slightly compressed; depth 291-368(mean=323) (in thousandth of standard length). Head 220-233 (mean=227), eye 48-54 (mean=51), large fish with relatively small eye. Snout 67-9[illegible] (mean=280); entire, without tubercles or pores; longer than eye diameter, shorter than interorbital space, usually shorter than the postorbital part of the head. Interorbital space slightly convex, 111-123 (mean=114). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels usually shorter than the maxillary ones. Ventral surface of upper lip consists of well developed, moderately long, undivided costae. Predorsal length 411-432 (mean=427); origin of dorsal fin opposite 9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin short with normal height, its fourth simple ray shorter than the base of dorsal fin, the length of fourth simple ray 230-242 (mean=238), and he base of dorsal fin 241-289 (mean=261); branched dorsal rays 11-12 (usually 11). The insertion of the dorsal fin opposite 18th-19th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from three to four. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 8th-9th scale of lateral line. Prepelvic length 491-519 (mean=506); pelvic fin insertion opposite 11th (rarely 10th) scale of lateral line. Preanal length 731-782 (mean=762); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st-22nd scale of lateral line. Caudal fin deeply forked. Its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 117-141 (mean=129); least depth of caudal peduncle 132-142 (mean=137), surrounded by 16 scale rows. Scales with parallel radii in the central part and radiating laterally; predorsal scales 9-10; circumferential scales 11/2/13, transverse scales (to the base of pelvic fin) 5.1/1/4.5. Lateral line scale 31-32, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly; its scales with simple tubes. Gill rakers on the first gill arch 28-34.

Preserved specimens are dark brown, and the dorsal part of head and back are darker than the lower part of the body. Body with plain uniform coloration, except that young specimens have a median lateral stripe which is distinct on the posterior half of the body and disappears in adults. All fins are plain.

Distribution

O. salsburyi is restricted to southern China to the province of Kwangtung and to Hainan Island; it probably occurs in N. Vietnam.

Habitat

Unknown

Material Examined (193 specimens, 54.3 mm–130.5mm standard length)

Holotype: AMNH 8371; Nodoa Hainan; Kwangtung Prov.

Other specimens:

AMNH 17745: (1 spec.), Kwangtung, near Canton
AMNH 10613: (1 spec.), Nodoa, Hainan
AMNH 10624: (12 spec.), Nodoa, Hainan
AMNH 10605: (40 spec.), Nodoa, Hainan
AMNH 10604: (35 spec.), Nodoa, Hainan
AMNH 10617: (14 spec.), Nodoa, Hainan
AMNH 10618: (18 spec.), Nodoa, Hainan
AMNH 10604 (22 spec.), no locality
AMNH 10609: (43 spec.), Nodoa, Hainan
NMNH 14861: (1 spec.), Nanning, Kwangsi
CAS 31763; (3 spec.), China
CAS 31791: (1 spec.), China
CAS 31792: (1 spec.), China

Table 2 Proportional measurements of *O. salsburyi* (measurements expressed as thousandth of standard length)

Characters	type	other specimens	
		mean	S.D.(n=192)
Depth	341	323	21.0
Head	226	227	5.2
Eye	54	51	3.0
Snout	81	80	6.3
Interorbital space	114	137	3.7
Base of dorsal fin	270	261	12.6
Fourth simple dorsal ray	250	238	5.0
Predorsal length		427	7.3
Prepelvic length		506	9.1
Preanal length		762	17.5
Third simple anal ray	195	190	4.7
Pectoral fin length	216	210	8.2
Pelvic fin length	203	201	5.4
Depth of caudal peduncle	142	137	3.7
Length of caudal peduncle	146	129	8.1
Lateral line scales	31	31.2	0.4
Predorsal scales	10	9.9	0.3
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	11	11.1	0.3
Pectoral rays	15	14.4	0.9
Gill rakers	28	31.4	2.4
Maxillary barbel	70	55	4.9
Rostral barbel	31	25	3.8

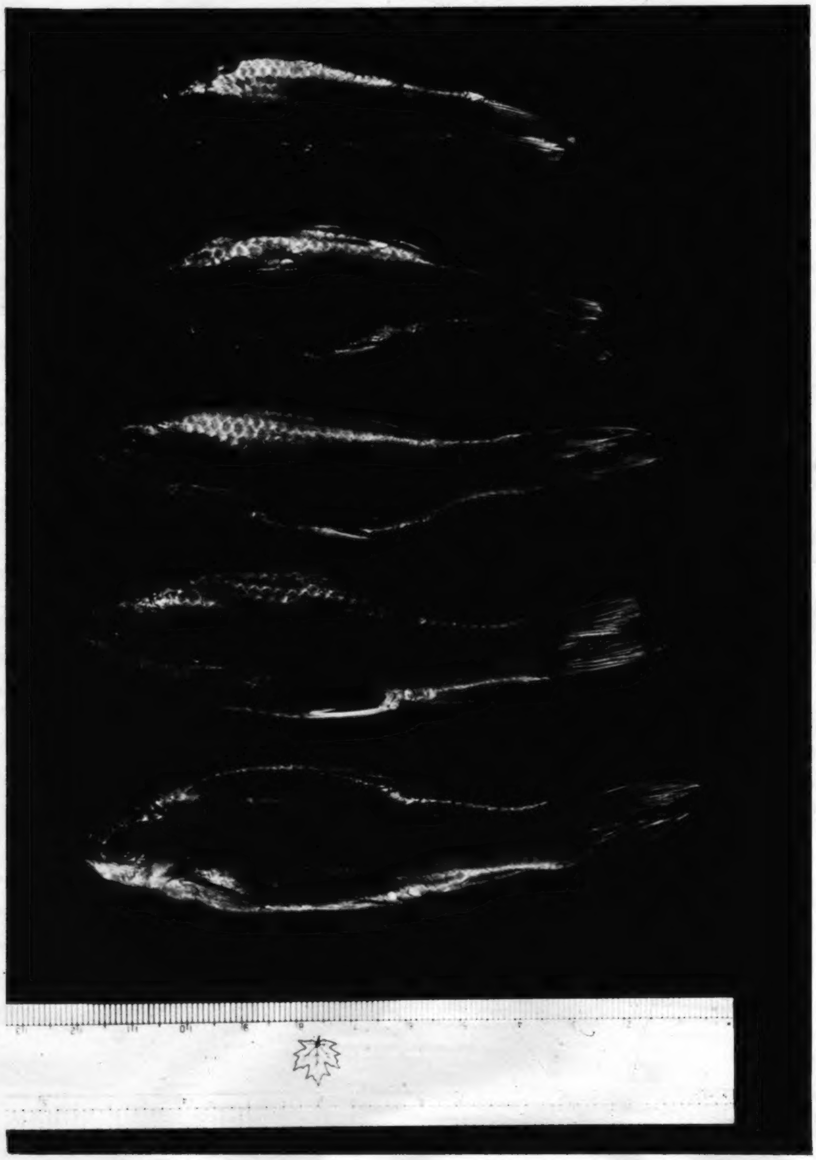

Fig. 3 *Osteochilus salsburyi* Nichols & Pope
AMNH 10609

Osteochilus brachynotopteroides Chevey

Osteochilus brachynotopteroides Chevey, 1934: p34-35; original description (in French); type locality: Lake Kontum, Vietnam; no type specimen.

Nomenclature

Chevey (1934) described and illustrated *O. brachynotopteroides* from specimens indicated in his paper as "13 cm. 50, and 14 cm. 50." This means he had two specimens, 13.5 and 14.5 cm. but I have failed to locate any of his specimens (they do not exist in either Vietnam or France). There is a single specimen in the British Museum no. BMNH 1933.8.19.30, labeled as *Osteochilus sp.*, Kontum, Annam; Delacour-Lowe, no collecting date; this specimen fits Chevey's description well. Since the specimen was cataloged in the British Museum in 1933, one year before Chevey's publication and was collected from the same locality, there is a strong possibility that this fish came from the collection of Chevey. Therefore, at this time, the specimen BMNH 1933.8.19.30 is the only known specimen of this species.

Diagnosis

D. IV,10; l.l. 33-34; c.f. 9/2/11; c.p. 16

O. brachynotopteroides is similar to *O. salsburyi*, but has a longer and more slender body. The dorsal fin has only 10 branched rays (usually 11 in *O. salsburyi*), circumferential scale 9/2/11 (11/2/13 in *O. salsburyi*), lateral line scales 33-34 (31 in *O. salsburyi*), and body plain.

Description

Body oblong, slender and slightly compressed, depth 282 (in thousandths of standard length). Head 214; eye 53, snout 78; no tubercles; snout longer than eye diameter, shorter than interorbital space, about equal to the postorbital part of the head.

Interorbital space convex, 116. Mouth subinferior, two pairs of well developed barbels; maxillary barbels about equal to eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed moderately long undivided costae. Predorsal length 429; origin of dorsal fin opposite 11th scale of lateral line before mid-point between tip of snout and caudal base and also before pelvic fin insertion. Dorsal fin small and short, its fourth simple ray 236, and the base of dorsal fin opposite 18 th scale of lateral line, number of scales from posterior base of dorsal fin to vertical from anal fin origin is 5. Tip of pectoral fin not reaching pelvic fin insertion, opposite 12th scale of lateral line. Prepelvic length 532; pelvic fin insertion opposite 14th scale of lateral line. Preanal length 789, anal fin concave third simple ray rather weak; anal fin origin opposite 23 rd scale of lateral line. Caudal fin forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 149; least depth of caudal peduncle 139, less than half of head length, and surrounded by 16 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales 10; circumferential scales 9/2/11; transverse scales 4.5/1/3.5 (to the base of pelvic fin), lateral line scales 34, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tube. Gill rakers on the first gill arch 31.

The specimen observed is very old and was not well preserved. It has plain yellowish coloration. According to Chevey's original description the back is greenish brown, yellowish-white below and a black spot on caudal penducle. The fins are all plain.

Distribution

Probably an endemic species of Lake Kontum, province of Pleiku, **Habitat**

According to Chevey (1934), Lake Kontum was formed in a crater of an extinct volcano at an altitude of 500 m above sea level. The greatest depth of this lake is 25 m. Oligochetes and insect larvae are abundant. Only three species of fish exist in the lake and two of them are endemic (chevy, 1934).

Material Examined (1 specimen, 104.3 mm in standard length)

BMNH 1933.8.19.30 (1 spec.) Kontum, Vietnam.

Table 3 Proportional Measurements of *O.brachynotopteroides* (measurements expressed as thousandths of standard length)

Characters	Measurements
Standard length (mm)	104.3
Depth	282
Head	214
Eye	53
Snout	79
Interorbital	116
Base of dorsal fin	216
Fourth simple dorsal ray	236
Predorsal length	429
Prepelvic length	32
Preanal length	789
Anal fin height	213
Pelvic fin length	200
Pectoral fin length	218
Depth of caudal peduncle	139
Length of caudal penduncle	150
Lateral line scales	34
Predorsal scales	10
Circumferential scales	9/1/11
Transverse scales	4.5/1/3.5
Circumpeduncular scales	16
Dorsal branched rays	10

Pectoral rays	13
Gill rakers	31
Maxillary barbels	35
Rostral barbels	21

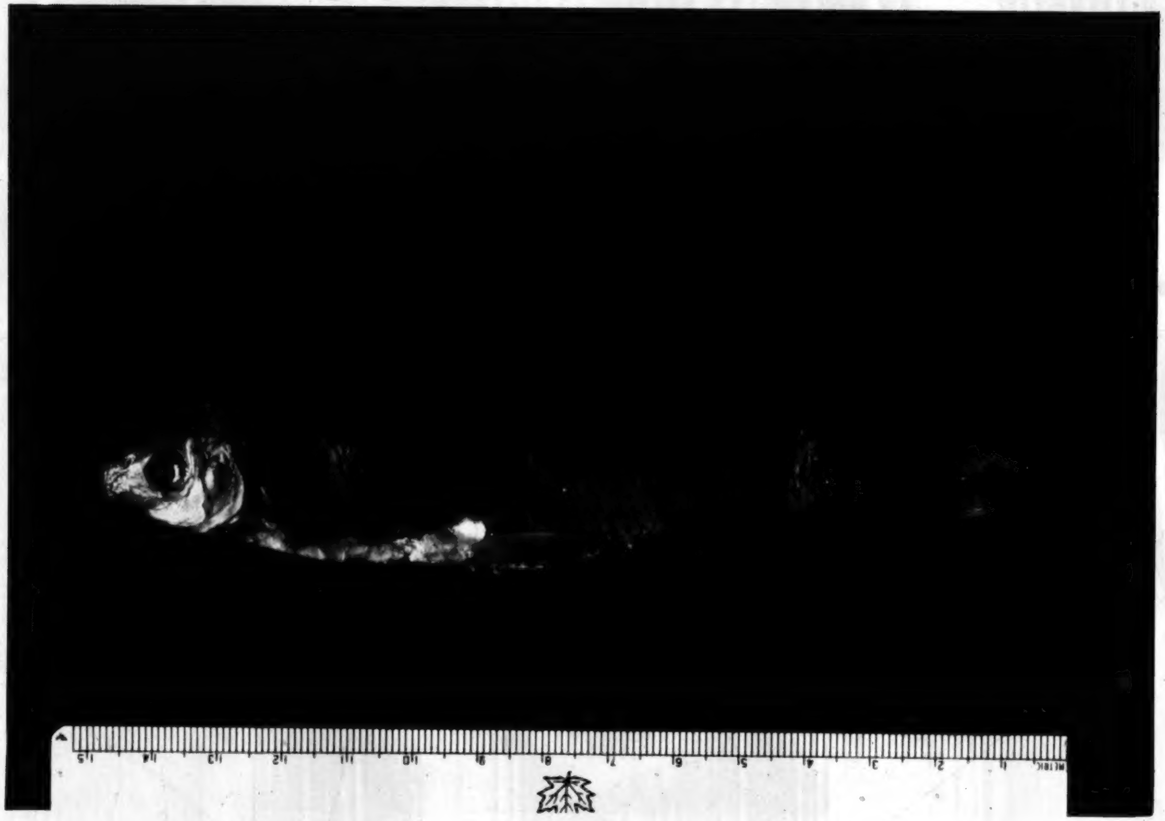

Fig. 4 Osteochilus brachynotopteroides Chevey BMNH 1933.8.19.30

Osteochilus waandersi (Bleeker)

Rohita waandersi Bleeker, 1852: p.733; original description; type locality: Toboali, Banka; holotype: BMNH 1866: 5.2.169, 198 mm total length (given by Bleeker), 150.4 mm standard length (my measurement).

Rohita (Rohita) waandersi Bleeker, 1860: vol.2, p.166; description;.....1863: vol.3, p.63; description with color plate (refers to the same specimen as in original description)

O. waandersi Gunther, 1868: vol.7, p.43; description (same specimen as Bleeker)

O.waandersi Weber and de Beaufort, 1916: vol 3, p.136; description (after Bleeker).

O. vittatus Weber and de Beaufort, 1916 (in part): vol 3, p.131; description; locality: Sumatra: Lake Sinkarah, Si-Djundjung, Solok; Borneo: Mendalan River.

O. vittatus Smith, 1945 (in part): p. 216, plt. 6.

Nomenclature

Bleeker described *Osteochilus waandersi* in 1852 from a single specimen. Bleeker's type specimen is quite peculiar in having circumferential scales 13/2/13 which are abnormal from the usual specimens which have 11/2/13 scales (the type specimen is the only specimen of this species I have seen which has the former number of circumferential scales). Later ichthyologists always identified specimens of this species as *O. microcephalus* because the circumferential scale number did not fit Bleeker's original description and *O. waandersi* has a median lateral stripe similar to those of *O. microcephalus* or *O. vittatus* (non Valenciennes). Most ichthyologists (after Bleeker's time such as Popta, Weber & de Beaufort, Fowler, Voltz, Smith, etc.) did not recognize that *O. waandersi* has a stripe that extends to the end of the mid-caudal rays while in *O. microcephlus* the stripe extends to the end of caudal peduncle (they thought that this was variation within one species). I have examined these two forms carefully from a large number of specimens and I believe they are different species as stated further in the diagnosis.

Diagnosis

D. IV,12–13; l.l 32–33; c.f. 11/2/13; c.p. 16; g.r. 40–60

O. waandersi has one or three tubercles on the snout, if three, the middle one is the largest. A distinct median lateral stripe on the body extends from the posterior border of the eye (or gill opening) to the end of caudal fin.

O. waandersi is very similar to *O. enneaporus* by sharing many characters such as: median lateral stripe, inferior mouth, number of scales, and number of branched dorsal rays. *O. waandersi* differs from *O. enneaporus* by having lighter pigment on the body (almost white on the bottom half). The median lateral stripe extends to the end of the caudal fin rays, while in *O. enneaporus* the stripe extends only to the end of the caudal peduncle. The third simple anal ray is shorter than the pectoral and pelvic fins in *O. waandersi*, but longer in *O. enneaporus*.

O.waandersi also shares some characters such as median lateral stripe and tubercles on the snout with *O. microcephalus* . However, *O. microcephalus* has fewer gill rakers (not more than 35 vs 40–60 in *O. waandersi*), and the stripe is extended to only the end of the caudal peduncle.

Description

Body oblong, slender, and slightly compressed; depth 299–334 (mean=308) in thousandths of standard length. Head 218–241 (mean=227); eye 43–60 (mean=51), large fish with relatively small eye. Snout 79–101 (mean=91); usually with three pointed tubercles at the front, the middle one the largest and lateral ones small or rudimentary. Some specimens have only one tubercle at the tip of the snout or all may be absent in young specimens. Snout longer than eye diameter, about equal to or shorter than interorbital space, usually longer than the postorbital part of the head. Interorbital space slightly convex, 97–122 (mean=111). Mouth conspicuously inferior; two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels usually shorter than the maxillary ones. Ventral surface of upper lip consists of well developed long costae, some of which are divided into two unequal portions. Predorsal length 398-442 (mean=427); origin of dorsal fin opposite 9th scale of lateral line; before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin short with normal height, its fourth simple ray usually shorter (it may be about equal to or a little longer) than the base of the dorsal fin, the length of the fourth simple ray 243-270 (mean=261), and the base of dorsal fin 261-306 (mean=270); branched dorsal rays 12-13. The insertion of the dorsal fin opposite 19th-20th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from the origin of the anal fin varies from two to three. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th-10th scale of lateral line. Prepelvic length 469-517 (mean=488); pelvic fin insertion opposite 11th-12th scale of lateral line. Preanal length 708-763 (mean=737); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st-23rd scale of lateral line. Caudal fin deeply forked. Its lobe more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 124-159 (mean=140); least depth of caudal peduncle 113-136 (mean=122), usually about equal to half of head length, and surrounded by 16 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales usually 10 (rarely 11); circumferential scales 11/2/13 and transverse scales (to the base of pelvic fin) 5.5/1/4.5. Lateral line scales 32-33, with two additional scales on the caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 40-60.

Preserved specimens are dusky on the upper two-fifths of the side, the dorsal part of the head and back are darker; the lower half of body whitish. A median longitudinal stripe on the body extends from the head to the end of the caudal rays. All fins are pinkish during life but hyaline in preserved specimens.

Distribution

Osteochilus waandersi ranges from central Thailand to Malay Peninsula, Sumatra, Java, and western Borneo.

Habitat

Forest streams and rivers with fast moving water swift current, water may be clear or turbid.

Material Examined (123 specimens 58.5-204.8 mm standard length)

Holotype: BMNH 1866.5.2.169, Tobali Province, Banka

Other specimens:

Borneo: BMNH 1881.3.21.11-12 (1 spec.) Sarawak
RMNH 2596 (2 spec.) no specific locality
ZMA 116.071 (1 spec.) Mendalam River
KCTR 76-36 (1 spec.) Kapuas River, 6 km west of Putussibau
KCTR 76-6 (7 spec.) Sungai Paklehung, low-lying hill stream, tributary of Sangai Mempawah, 48 km NNW from Pontianak.

Biliton Island: ZMA 116.075 (3 spec.) no specific locality

Malaysia: AMNH 13820 (1 spec.) no specific locality
BMNH 1922.5.19.59-63 (5 spec.) Tahan River

BMNH 1931.8.21.16 (1 spec.) River Jelai, Kuala Pilak, Negri Sembilan
BMNH 1932.5.19.15-16 (3 spec.) Tahan River Pahang
BMNH 1960.3.8.13 (1 spec.) Chegar Sirch, Tehan River, Pahang
CAS 36366 (1 spec.) no specific locality
CAS 34702 (1 spec.) Johore
CAS 34703 (1 spec.) no specific locality
NMNH 101228 (1 spec.) Mawai Region, Johore
ZMA 116.076 (2 spec.) Bukit Merah reservoir
NMS 2309 (3 spec.) Sungai Tembeling, Kuala Tahan, Pahang
NMS 1889 (1 spec.) Bukit Merah Reservior, Perak
NMS 1894 (3 spec.) Sedili River, Johore

Sumatra: RMNH 26904 (1 spec.) Deli
RMNH 29909 (5 spec.) Sockadana
RMNH 5009 (4 spec.) Sockadana
RMNH 5010 (4 spec.) Sockadana
ZMA 116.067 (2 spec.) Lake of Singkrah
ZMA 116.068 (1 spec.) River at Solok
ZMA 116.069 (2 spec.) Sidjoeungdjoeng
ZMA 116.077 (5 spec.) Patang Pangion, and Patang Sario

Thailand: ANSP 85835 (2 spec.) Khao Phanom Bencha
ANSP 76840 (1 spec.) Waterfall at Trang
ANSP 87833 (1 spec.) Old. Cheing Sen,

N. Siam

ANSP 76839 (6 spec.) Waterfall at Trang

AMNH 14578 1 spec.) Klong Chawang, East Bandon

BMNH 1934.12.18.16 (1 spec.) Chanthaburi

NMNH 108054 (1 spec.) Pakjong, head water of Manam Mun.

NMNH 103255 (2 spec.) Chanthabun River, southeast Thailand

NMNH 103256 (1 spec.) Klong Chawang, near Kao Nong, Bandon

NMNH 109785 (1 spec.) Mekong River

NMNH 191528 (1 spec.) no specific locality

NIFI (uncatalogued) (5 spec.) Kanjanburi

NIFI (uncatalogued) (3 spec.) Kanjanaburi

NIFI (uncatalogued) (10 spec.) Surathani

NIFI (uncatalogued) (5 spec.) Chumporn

NIFI (uncatalogued) (8 spec.) Kao Saming River, Trad

NIFI (uncatalogued) (9 spec.) Punnang Star, Yala.

Table 4 Proportional measurements of *O. waandersi* (measurements expressed as thousandth of standard length)

Characters	type	other specimens	
		mean	S.D.(n=122)
Depth	334	308	18.5
Head	237	227	10.4
Eye	55	51	6.3
Snout	100	91	7.4
Interorbital space	118	111	8.1
Base of dorsal fin	289	270	21.0
Fourth simple dorsal ray	243	261	10.3
Predorsal length	425	427	18.0
Prepelvic length	485	489	14.9
Preanal length	739	737	17.2
Third simple anal ray	184	199	9.7
Pectoral fin length	178	201	11.2
Pelvic fin length	204	205	7.6
Depth of caudal peduncle	136	122	7.9
Length of caudal peduncle	125	140	13.1
Lateral line scales	32	32.3	0.4
Predorsal scales	11	10.2	0.4
Circumferential scales	13/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	6.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	12	12.4	0.5
Pectoral rays	15	16.2	0.6
Gill rakers	41	47.0	5.3
Maxillary barbel	28	47 9.2	
Rostral barbel	25	33	5.7

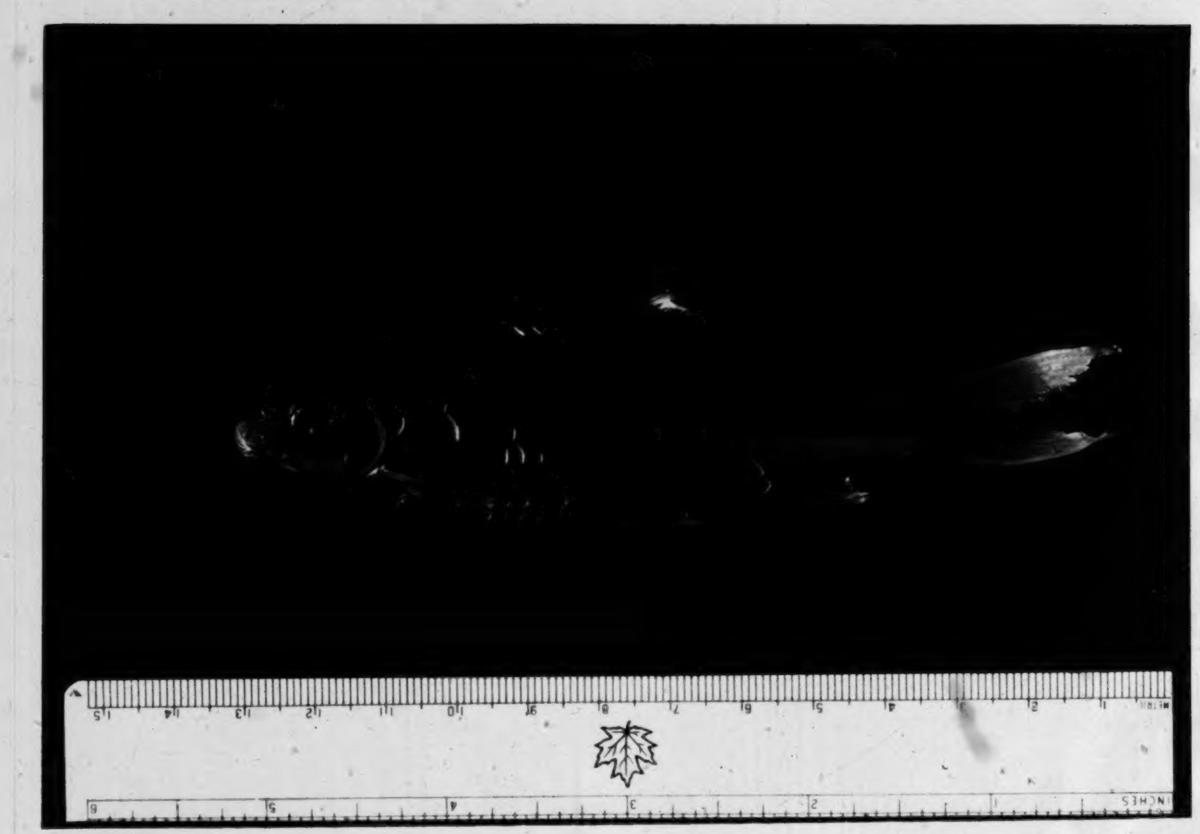

Fig. 5 Osteochilus waandersi (Bleeker) NIFI uncatalogued, Pattani River

Osteochilus enneaporus (Bleeker)

Rohita enneaporos Bleeker, 1852: p. 596; original description; type locality: Padang, Sumatra; holotype BMNH 1866.5.2.172, 191.9 mm standard length (my measurement)

Rihita (rohita) enneaporos Bleeker, 1860: vol 2, p.184; description .....1863: Vol3, P.70; description (with color plate).

Osteochilus vittatus Gunther (in part) 1868: vol.7, p.44; placed the species as a junior synonym of *O. vittatus*

Osteochilus vittatoides Popta, 1904: p195; original description; type locality: Howang River; head water of Mahakam, Borneo; syntypes (9 spec.), 93-116 mm total length (given by Popta), 80.5-89.2 mm standard length (my measurement). .....1906: p94, fig. 20; description, locality: Kajan River, eastern Borneo.

Osteochilus vittatus Weber & de Beaufort (in part) 1916: vol 3, p.131; placed the species as a junior synonym of *O. vittatus*.

Osteochilus scapularis Fowler, 1939: p69, fig. 17-18; original description; type locality: waterfall at Trang, S. Thailand; holotype ANSP 68505, 138 mm total length (given by Fowler) 97.1 mm standard length (my measurement).

Osteochilus scapularis Smith, 1945: p213; description (after Fowler).

Nomenclature

Osteochilus enneaporus was described by Bleeker (1852) on the basis of a single specimen. In 1868, Gunther considered the species a junior synonym of *O. vittatus* (none Cur.& Val.) because they have a similar median lateral stripe. Pota described *O. vittatoides* in 1904 from eastern Borneo; this differs from *O. enneaporus* by not having tubercles on the snout (this may be only a geographic variant; eastern Borneo is quite isolated from the rest of the fauna). Weber and de Beaufort (1916) considered both *O. enneaporus* and *O. vittatoides* to be junior synonyms of *O. vittatus* (non

Valenciennes). He probably did not see the types of the three species since he stated: "The above description is in accordance with that of Bleeker given for *Rohita vittatus*." My examination of the type specimens of these species and few other specimens of *O. eneaporus* strongly suggests that *O.eneaporus* is a valid species.

Diagnosis

D. IV,11-13; l.l. 31-32; c.f. 11/2/13; c.p. 16; g.r. 40-60

O. enneaporus has either one or three tubercles on the snout (if three the middle one is the largest). There is a median lateral stripe along side of the body which is usually distinct on posterior half of the body. Body covered with darked melanin pigment.

O. enneaporus is very closely related to *O. waandersi* and shares characters such as: median lateral stripe, conspicuously inferior mouth, number of scales, and number of branched dorsal rays. *O. enneaporus* differs from *O. waandersi* by having darker body coloration (usually very dark on the anterior and dorsal part of the body) and a rather blunt (truncate) snout while in *O. waandersi* the snout is quite pointed. The median lateral stripe extends only to the end of the caudal peduncle or diffusely into the middle of the caudal fin, but extends to the end of the caudal rays as a sharp, distinct band in *O. waandersi*.

Description

Body oblong, slender, and slightly compressed; depth 289-344(mean=319)(in thousandths of standard length). Head 207-262 (mean=229); eye 45-64 (mean=52), large fish with relatively small eye. Snout 79-105 (mean=94); usually with one pointed or three tubercles or pores at the front, the middle one the largest and lateral ones small or rudimentary; snout longer than eye diameter in adult fish, shorter than interorbital space, longer than the postorbital part of head. Interorbital space slightly convex, 108-123 (mean=113). Mouth conspicuously inferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary one. Ventral surface of upper lip consists of well developed, long, undivided costae. Predorsal length 425-452 (mean=435); origin of dorsal fin opposite 8th-9th scales of lateral line before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually falcate, its fourth simple ray usually longer than the base of dorsal fin, length of the fourth simple ray 293-376 (mean=329), base of dorsal fin 259-292 (mean=279), and branched dorsal rays 11-12. The insertion of the dorsal fin opposite 19th-20th scale of lateral line, number of scale from insertion of the dorsal fin to vertical from the anal fin origin varies from one to two. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 10th-12th scale of the lateral line. Prepelvic length 498-530 (mean=509); pelvic fin insertion opposite 11th scale of lateral line. Preanal length 730-751 (mean=743); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st - 22nd scales of lateral line. Caudal fin deeply forked, its lobe more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 126-146 (mean=137); least depth of caudal peduncle 128-138 (mean=132), usually less than half of head length, and surrounded by 16 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales usually 10 (rarely 9); circumferential scales 11/2/13, and transverse scales (to the base of pelvic fin) 5.5/1/4.5. Lateral line scales 31-32, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 40-60.

Preserved specimens with dark body, upper part of side and head darker than the lower part. A median longitudinal stripe extends from head to the end of caudal peduncle, more distinct on posterior half of body. This stripe may be diffuse in the middle part of caudal fin in large specimens. Dorsal and caudal fins dusky, other fins plain. Live specimens have bright red fins.

Distribution

The distribution of *O. enneaporus* is restricted to Malay Peninsula, Sumatra, and Borneo. It is quite common in the Kapuas River and in Sarawak. Only a few specimens are available from Sumatra and Malay Peninsula.

Habitat

Small or large forest streams with swift or moderate current, usually found in clear water; bottom sand, gravel, stones, and logs.

Material Examined (46 specimens, 61.1-191.9 mm standard length)

Holotype: BMNH 1866.5.2.172; Padang Sumatra

Other specimens:

Borneo : BMNH 1978.3.20.112 (1 spec.) S. Malinau, Sarawak

BMNH 1978.3.20.113-114 (2 spec.) S.Lansat, Sarawak

BMNH 1978.3.20.115 (1 spec.) S. Berar, Sarawak

BMNH 1978.3.20.116 (1 spec.) S. Melinau, Sarawak

BMNH 1894.6.30.185 (1 spec.) Padas River

BMNH 1906.10.29.5-6 (2 spec.) head of Baram River

KCTR 76-29 (4 spec.) Rocky channel in mainstream of Sungai Pinoh at Nanga Saian, 45 kmsouth of Nanga Pinoh.

KCTR 76-6 (7 spec.) Sungai Pukleung, low-lying forest hill stream, tributary of Sungai Menpawah, 48 km NNW from Pontianak, 9 km NE of Andjongan.

KCTR 76-27 (6 spec.) rocky channel in mainstream of Sungai Pinoh, 37 km S of Nangapinoh.

KCTR 76-24 (1 spec.) main stream, Sungai Pinoh 20-60 km upstream from Nangapinoh

RMNH 7575 (9 spec.) (syntypes of *O. vittatoides*)
    Howang River
RMNH 7576 (4 spec.) Kajan River

Sumatra: BMNH 1915.8.24.11 (1spec.) Sungai Pinoh, Korinchi

Malay Peninsula: NMS 1890 (2 spec.) Ulu Jelai, Pahang,
    Malaysia
  NMS 2656 (1 spec.) River Jalai, Kuala
    Pilah, Negri Sembilan, Malaysia.
  ANSP 68505 (1 spec.) (holotype of
    O. scapularis) waterfall
    at Trang Thailand
  NIFI uncatalogued (1 spec.) Patani River at
    Yala, Thailand

Table 5 Proportional measurements of *O. enneaporus.* (measurements expressed as thousandths of standard length)

Characters	type	other specimens	
		mean	S.D.(n=45)
Depth	289	319	19.1
Head	207	229	15.2
Eye	45	52	6.0
Snout	79	94	9.7
Interorbital space	110	113	6.4
Base of dorsal fin	260	279	12.8
Fourth simple dorsal ray	333	329	44.2
Predorsal length		435	10.3
Prepelvic length		509	11.6
Preanal length		743	9.1
Third simple anal ray	223	248	15.7
Pectoral fin length	193	228	18.4
Pelvic fin length	217	243	16.1
Depth of caudal peduncle	138	132	4.1
Length of caudal peduncle	144	137	7.0
Lateral line scales	32	31.3	0.6
Predorsal scales	10	9.8	0.4
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	12	11.8	0.4
Pectoral rays	16	15.6	0.5
Gill rakers	app.60	51.6	7.0
Maxillary barbel	54	60	8.6
Rostral barbel	22	36	6.9

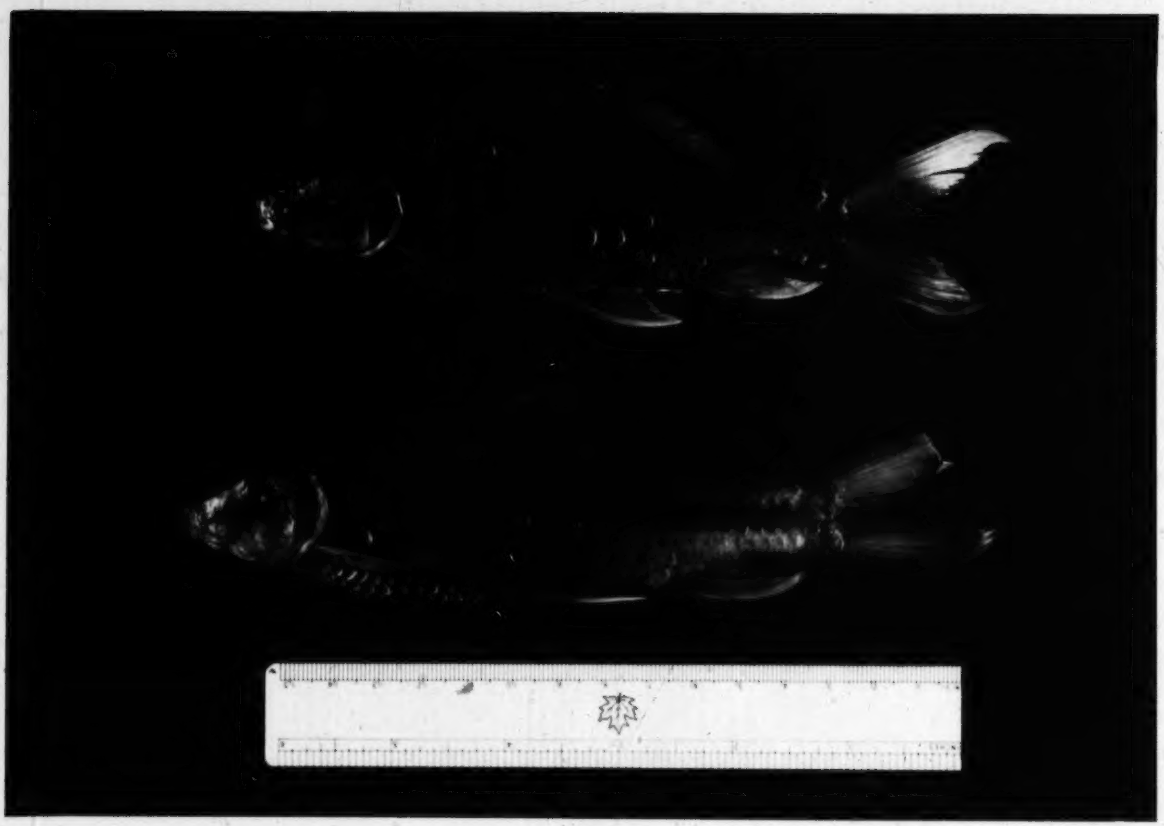

Fig. 6 *Osteochilus enneaporus* (Bleeker) KCTR 76-6

Osteochilus bellus Popta

Osteochilus bellus Popta, 1904: p.197; original description; type locality:Borneo (Bo River); Syntype, RMNH 7580, six specimens: 80-112 mm total length (given by Popta), 61.5-84.9 mm standard length (my measurements).

Osteochilus bellus Popta, 1906: p.104; redescription of the same specimens.

Osteochilus bellus Weber & de Beaufort, 1916: vol.3, p.134; description refering to Popta's specimens.

Nomenclature

Popta described *O. bellus* from six specimens collected from River Bo in 1904. Since then no additional specimens have been collected. The six syntypes demonstrate intraspecific variations in colour pattern and snout tubercles. I do not intend to designate a lectotype.

Diagnosis

D. IV,10-11; l.l. 31; c.f. 9/2/11; c.p. 16

Ostechilus bellus has about six longitudinal rows of spots on the body, and a median lateral stripe on the posterior half of the body which is less distinct in some specimens. Mouth conspicuously inferior, lower lips with well developed long costae. Gill rakers on the first gill arch 43-45.

O. bellus has a body proportion similar to *O. sarawakensis* but it has fewer circumferential scales, a shorter dorsal fin, and tubercles on the snout. It also shares some characters with *O. enneaporus* such as the median lateral stripe, tubercles on the snout, and the mouth structure and position. *O. bellus* has fewer circumferential scales, a shorter dorsal fin, and a less distinct lateral stripe than *O. enneaporus*. Also, *O. enneaporus* does not have rows of spots on the body.

Description

Body oblong, slender and slightly compressed, depth 249-304 (mean=284.3) (in thousandths of standard length). Head 217-241 (mean=234); eye 54-66 (mean=61). Snout 84-109 (mean=97); usually with three pointed tubercles in the front, the middle one the largest; in some specimens many small tubercles present. Snout longer than eye diameter in adult fish, slightly shorter than interorbital space, slightly convex; length 100-108 (mean=104). Mouth conspicuously inferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed long undivided costae. Predorsal length 402-446 (mean=418); origin of dorsal fin opposite 8th-9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic insertion. Dorsal fin falcate, its fourth simple rays moderately produced, longer than the base of dorsal fin. The length of the fourth simple ray 273-300 (mean=290), and the base of dorsal fin 241-270 (mean=259); branched dorsal rays 10-11. The insertion of the dorsal fin opposite 18th-19th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from two to three. Tip of pectoral fin usually not reaching the pelvic fin insertion, opposite 10 th scale of lateral line. Preanal length 729-764 (mean=743); anal fin concave, third simple ray rather than week; anal fin origin opposite 21st scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than lower lobe. Length of caudal peduncle 124-148 (mean=137); least depth of caudal peduncle 119-127 (mean=124), usually about half of the head length, and surrounded by 16 scale rows. Scales with parallel radii, predorsal scales usually 9 (10 in one species); circumferential scales 9/2/11 (one specimen 10/2/11) (4.5/1/3.5 in transverse series to the base of the pelvic fin); lateral line scales 3 with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly its scales with simple tubes. Gill rakers on the first gill arch 43-45.

Preserved specimens are dark with pigment, the dorsal head and back are very dark. Body with median longitudinal stripe on posterior half of body more or less distinct; 5-6 rows of spots along side of the body (situated in the pocket of each scale), three below, two above, and one on the lateral line; the middle 4 rows are more distinct than the outer two. Dorsal fin and caudal fins with melanin pigment, other fin hyaline. Coloration of fresh or live specimens according to Popta (1906), is violet above, pinkish-violet below; the dorsal and caudal fins are grayish-pink, other fins hyaline-pink.

Distribution

Only six specimens are known and all are from River Bo, left branch of the superior Mahakam, Central Boneo.

Habitat

Popta (1906) states that it occurs in a mountain stream about 150 metres above sea level.

Material Examined (6 specimens, 61.5 mm-84.9 mm. standard length)

RMNH 7580 (syntypes): River Bo, Central Borneo.

Table 6 Proportional Measurements of *O. bellus* (measurements expressed as thousandths of standard length)

Characters	Syntypes			
	1	2	3	4
Standard length (mm)	84.9	83.0	76.0	72.7
Depth	304	277	299	292
Head	236	217	239	230
Eye	54	57	66	61
Snout	109	84	95	89
Interorbital	108	104	105	100
Base of dorsal fin	270	253	263	272
Fourth simple dorsal ray	298	273	300	279
Predorsal length	424	402	417	404
Prepelvic length	504	492	521	498
Preanal length	762	729	753	732
Anal fin height	238	218	234	213
Pelvic fin length	240	213	232	215
Pectoral fin length	244	224	234	223
Depth of caudal peduncle	126	123	126	122
Length of caudal penduncle	145	133	146	149
Lateral line scales	31	31	31	31
Predorsal scales	9	9	10	9
Circumferential scales				
Transverse scales				
Circumpeduncular scales	16	16	16	16

Dorsal branched rays	11	10	11	11
Pectoral rays	16	16	16	16
Gill rakers		43	45	43
Maxillary barbels	94	90	76	97
Rostral barbels	67	51	63	62

Table 7 Proportional Measurements of *O. bellus* (measurements expressed as thousandths of standard length)

Characters	syntypes			
	5	6	mean	S.D.(n=6)
Standard length (mm)	71.0	61.5		
Depth	249	284	284	19.8
Head	241	244	234	9.7
Eye	65	63	61	4.7
Snout	06	102	97	9.9
Interorbital	105	102	104	2.8
Base of dorsal fin length	254	241	259	11.8
Fourth simple dorsal ray	299	288	289	11.5
Predorsal length	415	446	418	16.0
Prepelvic length	520	520	509	12.8
Preanal length	721	764	743	18.4
Anal fin height	235	234	229	10.4
Pelvic fin length	224	231	226	10.5
Pectoral fin length	239	242	234	9.0
Depth of caudal peduncle	120	127	124	2.8
Length of caudal penduncle	124	124	137	11.4
Lateral line scales	31	31	30.9	0.3
Predorsal scales	9	9	9.2 0.4	
Circumferential scales				
Transverse scales				
Circumpeduncular scales	16	16		

Dorsal branched rays	10	10	10.5	0.5
Pectoral rays	15	15	15.7	0.5
Gill rakers		35	41.3	4.9
Maxillary barbels	93	88	89.7	7.4
Rostral barbels	52	54	58.2	6.7

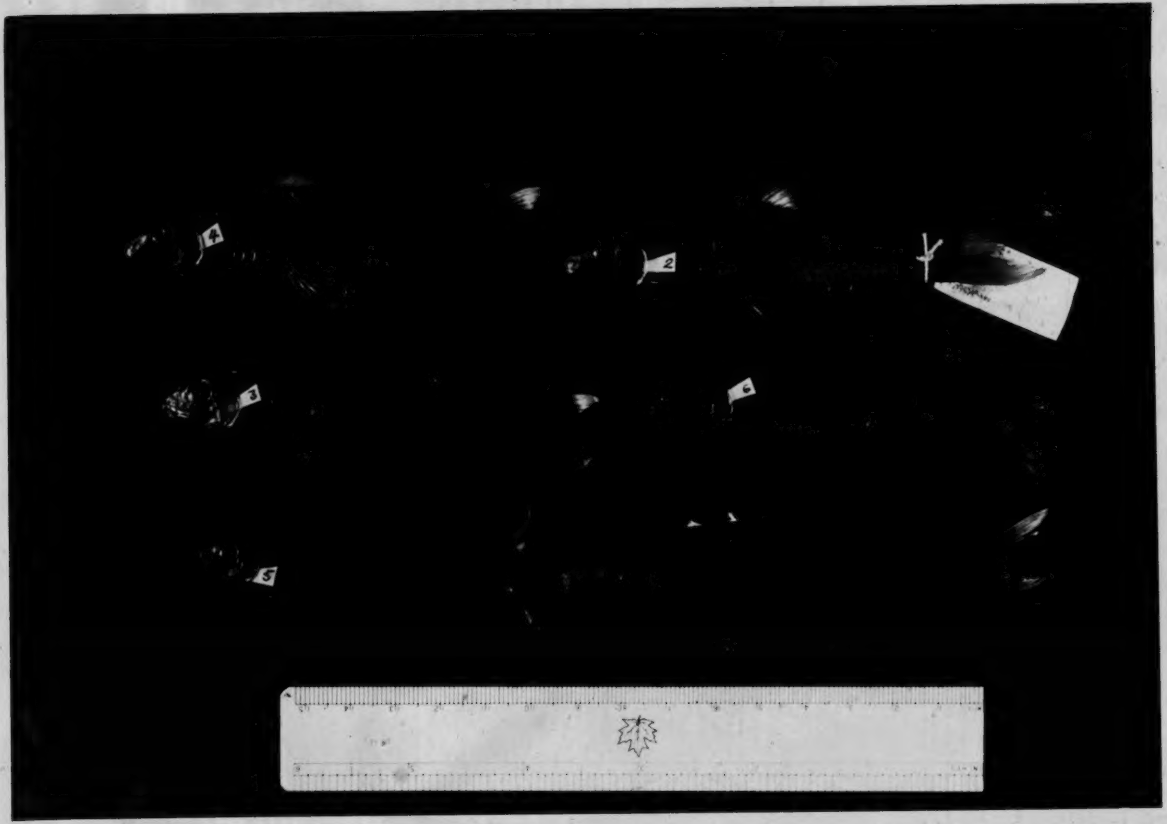

Fig. 7 Osteochilus bellus Popta Syntypes RMNH 7580

Osteochilus pleurotaenia (Bleeker)

Lobochilus pleurotaenia Bleeker, 1855: p.267; original description; type locality; Lahat, Sumatra; syntypes, BMNH 1866.5.2.105 (1 spec.), RMNH 6998 (1 spec.), 145 mm and 216 mm. total length (given by Bleeker), 103.0 and 150.2 mm standard length (my measurements).

Lobochilus rohitoides Bleeker, 1857: p.363; original description; type locality; Krawang, Batavia (Java); Holotype, BMBH 1866.6.2.163, 68 mm total length (given by Bleeker), 46.1.mm standard length (my measurement).

Diplocheilichthys pleurotaenia Bleeker, 1860: p.143; description of new generic name; species *Lobocheilos pleurotaenia* Bleeker.

Labeo (Diplocheilos) rohitoides Bleeker, 1860: p.139; description.

Diplocheilichthys pleurotaenia Bleeker, 1863: Vol.3, p.55; description with color plate.

Labeo pleurotaenia Gunther, 1868: Vol.7, p.58; description, synonymized *Labeo (Diplocheilos) rohitoides* Bleeker under *Labeo pleurotaenia* (Bleeker)

Osteochilus jentinkii Popta, 1904: p.194; original description; type locality: Bongon River (Borneo); syntypes, RMNH 7574 (2 spec.) 181 mm, and 194 mm. total length (given by Popta), 131.2 mm and 135.8 mm (my measurements)

Osteochilus jentinkii Popta, 1906: p.91; redescription with plate.

Labeo (Labeo) rohitoides Weber & de Beaufort, 1916: Vol.3, p. 214; description; locality: Sumatra (Sidjungdjung); synomyzed *Osteochilus jentinkii* under this name.

Labeo (Labeo) pleurotaenia Weber & de Beaufort, 1916: Vol.3, p.215; description; locality: Borneo, middle and upper part of River Kapuas.

Nomenclature

Bleeker described *Osteochilus pleurotaenia* under the name *Lobocheilos pleurotaenia* in 1855 from two specimens from Sumatra and in 1857 he described

Lobocheilos rohitoides from a single specimen from Batavia. In these descriptions there are only minor differences. In 1860, Bleeker proposed the new generic name *Diplocheilichthys* for *Lobochilos pleutaenia* (monotypic form) and placed *Lobocheilos rohitoides* under *Labeo (Diplocheilos) rohitoides.* Gunther (1868) synonymized these two species and placed them under *Labeo.* He did not recognized the subgenera of Bleeker. In 1904, Popta described *Osteochilus jentinki* from two specimens collected from Bongan, Central Borneo, which were synonymized under *Labeo rohitoides* by Weber & de Beaufort (1916). Weber and de Beaufort (1916) recognized *Labeo pleurotaenia* and *Labeo rohitoides* as separate species by the difference of the lateral part of the upper labial fold which they called the lateral lobe of snout, based on comparing type specimens of *Osteochilus jentinki* (representing *Labeo rohitoides*), without seeing the type of *Lobocheilos rohitoides,* and the type specimen of *Lobochilos pleurotaenia* in RMNH. I have examined type specimens of these three species and agree with Gunther, in part, that *Lobocheilos pleurotaenia* and *Lobocheilos rohitoides* are the same species and that *Osteochilus jentinki* is also a synonym of this species. The shape of the labial folds in this species resembles those of *Labeo* but when the detailed structure of the costae on the labial folds and the osteological structures are carefully studied, it is evident that this species belongs to *Osteochilus.* Placement of this species in *Osteochilus* poses a nomenclatural problem since *Osteochilos pleurotaenia* is a type species for the genus *Diplocheilichthys* which is an *Osteochilus.* However, the name *Diplocheilichthys,* almost forgotten, had been used only by Bleeker in 1860 and 1863. *Osteochilus* is a well known genus for ichthyologists who study cyprinids. Therefore, I intend to appeal to the International Commision of Nomenclature to stabilize the name *Osteochilus* and suppress the name *Diplocheilichthys.*

Diagnosis

D. IV,10–11; l.l. 30–31; c.f. 11/1/13; c.p. 16.

O. pleurotaenia has 10 branched dorsal rays. Mouth is conspicuously inferior. Upper labial fold (upper lip) expanded to form a large sucking mouth. Ventral part of upper lip with well developed, long, and undivided costae. Snout without major tubercle but with numerous fine tubercles or entire. Gill rakers on the first gill arch numerous, 40–60.

O. pleurotaenia shares many characters with *O. enneaporus* but *O. pleurotaenia* has only 10–11 branched dorsal rays while *O. enneaporus* usually has 12–13 (rarely 11). *O. enneaporus* has three tubercles on snout, which are lacking in *O. pleurotaenia*. The median lateral band is more distinct in *O. enneaporus* but always disappears in adult specimens of *O. pleurotaenia*. The lips are more expanded in *O. pleurotaenia*.

Description

Body long, slender, and slightly compressed, depth 253–307 (mean=270) (thousandths of standard length). Head 195–302 (mean=251); eye 54–78 (mean=62), larger fish with relatively small eye. Snout 89–130 (mean=105); without major tubercles but with numerous fine granulated tubercles or entire snout longer than eye diameter in adult fish, shorter than interorbital space, about equal to the postorbital part of the head. Interorbital space slightly convex, 105–125 (mean=113). Mouth conspicuously inferior, two pairs of well developed barbels; maxillary barbels usually shorter than or equal to eye diameter, rostral barbels shorter than the maxillary ones. Lips expanded, forming a sucking mouth; ventral surface of upper lip consists of well developed, long, undivided costae. Predorsal length 455–503 (mean=474); origin of dorsal fin opposite 8th or 9th (usually 9th) scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually falcate, its fourth simple ray greatly produced, longer than the base of dorsal fin, the length of the fourth simple ray 230–291 (mean=260), and the base of dorsal fin 200–230 (mean=211); branched dorsal rays 10–11. The insertion of the dorsal fin lies opposite the 16th–18th scale of the lateral line; number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from four to five. Tip of pectoral fin not reaching the pelvic fin insertion , usually opposite 8th–10th scale of lateral line. Prepelvic length 547–578 (mean=562); pelvic fin insertion opposite 11th–12th scale of lateral line. Preanal length 773–801 (mean=787); anal fin concave, third simple ray rather weak; anal fin origin opposite 22nd–23rd scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 124–174 (mean=143); least depth of caudal peduncle 106–135 (mean=116), usually slightly longer than half of head length, shorter than its length, and surrounded by 16 scale rows. Scale with nearly parallel longitudinal radii, predorsal scales 10–11; circumferential 11/2/13 (5.5/1/4.5 intransverse series to the base of pelvic fin); lateral line scales 30–31, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 28–31.

Preserved specimens are dusky on the upper two-fifths of the side; the dorsal part of head and back are darker than the rest of the body. A median lateral stripe runs from the gill opening to the end of caudal peduncle, usually more distinct in younger specimens and may be absent in adults. All fins are plain. According to Bleeker's description, body color is green dorsally and silver ventrally, dorsolateral scales with dark triangular spots. Fins are orange-pink.

Distribution

O. pleurotaenia is not a common species, the distribution is limited to Sumatra, Java, and Borneo.

Habitat

Unknown, probably large streams at high elevation with fast running water.

Material Examined (19 specimens; 43.4–224.7 mm. standard length)

Syntypes: BMNH 1866.5.2.105 (1 spec.), Lahat, Sumatra
RMNH 6998 (1 spec.), Lahat, Sumatra

Other type specimens:

BMNH 1866.6.2.163, Holotype of *Lobocheilos rohitoides*; Krawang, Batavia, Java.

RMNH 7574, syntypes (2 spec.) of *Osteochilus jentinkii* ; Bongan River, Central Borneo.

Other specimens:

Borneo: RMNH 1683-86 (5 spec.), 3 specimens from Putussibau, Kapuas River; 2 specimens from Mandai River, tributary of Kapuas at Nangaraun.

Sumatra: UMMZ 169799 (6 spec.), Moesi River at Moeara Klingi.

No locality: RMNH 16587 (3 spec.) from Dr.Bleeker's collection.

Table 8 Proportional Measurements of *O. pleurotaenia* (measurements expressed as thousandths of standard length)

Characters	Syntypes		Others (n=19)	
			mean	S.D.(n-1)
Standard length(mm)	103.0	150.2		
Depth	270	278	270	15.2
Head	233	235	251	32.6
Eye	61	62	62	11.7
Snout	94	91	105	12.5
Interorbital	114	125	113	6.0
Base of dorsal fin	209	220	211	12.8
Fourth simple dorsal ray	242	incom	260	18.3
Predorsal length			474	17.8
Prepelvic length			562	11.4
Preanal length			787	9.8
Anal fin height	235	incom	213	22.9
Pelvic fin length	238	incom	216	19.1
Pectoral fin length	223	incom	217	10.7
Depth of caudal peduncle	126	125	116	7.7
Length of caudal penduncle	152	148	148	15.0
Lateral line scales	31	31-32	30.9	0.6
Predorsal scales	10	10	10.2	0.4
Circumferential scales				
Transverse scales				
Circumpeduncular scales	16	16	16	

Dorsal branched rays	10	10	10.3	0.5
Pectoral rays	16	17	15.7	0.8
Gill rakers	36	48	44.5	7.2
Maxillary barbels	52	53	52	6.0
Rostral barbels	39	32	36	6.7

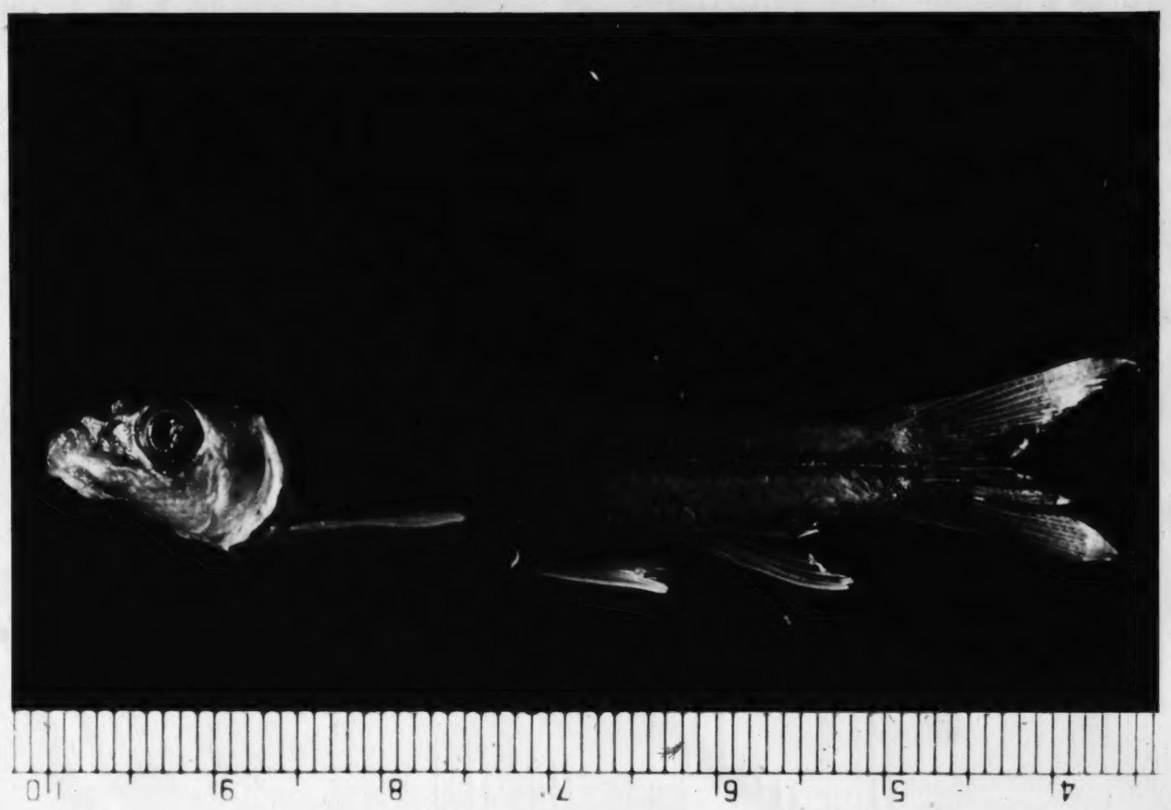

Fig. 8 Osteochilus pleurotaenia (Bleeker) UMMZ 169799

Osteochilus kahajanensis kahajanensis (Bleeker)

Rohita kahajanensis Bleeker, 1957: p.18; original description; type locality: Kahajan River, Southern Borneo; holotype specimen RMNH 4980, 76 mm total length (given by Bleeker) 53.9 mm standard length (my measurement).

Rohita (Rohita) kahajanensis, 1860: vol 2, p180; description; refers to the same specimen. 1863: vol.3, p69; description; one additional specimen of 106 mm total length from Lahat, Sumatra (BMNH 1866-5-2-175, 78.7 mm SL.)

Osteochilus kahajanensis Gunther, 1868: vol.7, p.44; description; reference to Bleeker's specimen.

Osteochilus kahajanensis Popta, 1906: p.98; description; locality: Bo River, tributtary of Mahakam, Central Boneo.

Osteochilus kahajanensis Weber & de Beaufort, 1916: vol3, p130; description; locality: Kapuas River at Putus Sibau.

Nomenclature

Osteochilus kahajenensis was described from a single specimen by Bleeker in 1857. The type specimen is 76 mm long (total length, stated by Bleeker). Gunther (1868) claimed that the specimen BMNH 1866.5.2.175 (78.7 mm standard length) purchased from Bleeker's collection, is a type of the species. The specimen at the BMNH is probably the second specimen that Bleeker had in his 1863 Atlas, which he indicated was 106 mm (total length) long. The specimen RMHN 4980 (53.9 mm S.L.) indicated as a syntype agrees with the total length that Bleeker gave in the original description, and therefore this specimen is probably the holotype, while the specimen at the BMNH would not be a type.

Diagnosis

D. IV,15–17 (rarely 14); l.l. 31–32; c.f. 11/2/13; c.p. 16

O. kahajenensis is the only species of *Osteochilus* that has two well developed tubercles on the snout (one on each side) (there is usually one or three or more in some other species). A diffuse median longitudinal stripe along the side of the body (unlike the distinct median lateral stripe found in the *O. microcephalus* and *O. waandersi* groups). There is geographical variation in the number of branched dorsal rays and body proportions between the populations in most regions (D. IV,15–16) and in the populations in the isolated area of northeastern Borneo (D. IV,12–14). The latter form is described as a new subspecies *O. kahjenensis chini* in this study (see page 84).

Description

Body oblong and compressed; depth 322–394 (mean=347) (in thousandths of standard length). Head 201–262 (mean=220); eye 39–71 (mean=49), large fish with relatively small eye. Snout 77–93 (mean=85); with two tubercles or pores in front, snout longer than eye diameter in adult fish, shorter than interorbital space. Interorbital space slightly convex 103–119 (mean=111). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbel usually shorter than the maxillary ones. Ventral surface of upper lip consists of well developed moderately long undivided costae. Predorsal length 425–456 (mean=438); origin of dorsal fin opposite 8th or 9th (usually 9th) scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin moderately long and normal in height, the length of its fourth simple ray 209–337 (mean=240), and the base of dorsal fin 333–394 (mean=365); branched dorsal rays 15–16 (rarely 14). Insertion of the dorsal fin opposite 22nd–23rd scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from zero to one. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 7th–11th scale of lateral line. Prepelvic length 489–521 (mean=506), pelvic fin insertion opposite 11th–12th scale of lateral line. Preanal length 753–782 (mean=768), anal fin concave, third simple ray rather weak; anal fin origin opposite 22nd–24th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 105–128 (mean=121); least depth of caudal peduncle 126–146 (mean=134), usually less than half of head length, and surrounded by 16 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales usually 10 (rarely 9); lateral line scale 31–32 with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly; its scales with simple tubes. Gill rakers on the first gill arch 33–46 (mean=39.8).

Preserved specimens are dusky on the upper part of the side, the dorsal part of head and back are darker. An intense dark spot occurs behind the upper part of the gill opening. A wide diffuse median lateral stripe which is wider at the anterior part and tapers posteriorly extends from the gill opening to the end of the caudal peduncle. A large round black spot is on the middle part of caudal peduncle. Membranes of dorsal and anal fin are dusky; other fins plain.

Distribution

O. kahajenensis kahajenensis occurs only in eastern of Malay Penninsula, Southern Sumatra, Java and Western Borneo.

Habitat

Small or large streams at low altitude, current moderate to swift, water usually turbid, muddy or sandy bottom.

Material Examined (14 specimens, 53.9–219.2 mm S.L.)

Holotype: RMNH 4980 Kahajan River, Borneo

Other specimens: BMNH 1866-5-2-175 no locality, from
Bleeker's collection, probably Lahat,

Sumatra.

RMNH 17760 (1 spec.) Bleeker's collection,
no locality.

Borneo: BMNH 1895.7.2.59-60 (3 spec.), Baram District,
Sarawak.
BMNH 1978.9.5.44 (1 spec.) S. Lansat River, Sarawak
BMNH 1978.3.20.111 (1 spec.) S.Melinau Paku,
Sarwak
BMNH 1978.3.20.110 (1 spec.) Melinau River, Sarawak
KCTR 76-17 (1 spec.) small forest stream where it
flows into Kapaus main stream about 10 km
upstream from Sanggau.
ZMA 116.082 (1 spec.) Putus Sibau.

Sumatra: ZMA 116.083 (1 spec.) Kurintji

Malaysia: BMNH 1922.5.19.75-76 (2 spec.) Tahan River

Table 9 Proportional measuremants of *O. kahajanensis kahajanensis* Measurements expressed as thousandths of standard length)

Characters	type	other specimens	
		mean	S.D.(n=13)
Depth	299	347	26.7
Head	263	220	15.5
Eye	71	49	9.7
Snout	87	85	4.7
Interorbital space	105	111	5.1
Base of dorsal fin	334	365	19.4
Fourth simple dorsal ray	217	240	31.5
Predorsal length		438	14.6
Prepelvic length		506	21.2
Preanal length		768	24.4
Third simple anal ray	197	201	6.0
Pectoral fin length	191	212	13.1
Pelvic fin length	198	213	11.3
Depth of caudal peduncle	130	134	6.6
Length of caudal peduncle	121	121	12.7
Lateral line scales	30	31.7	0.6
Predorsal scales	10	9.9	0.4
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	15	15.1	0.8
Pectoral rays	15	15.9	0.7
Gill rakers	incomp.	39.8	4.6
Maxillary barbel	87	65	12.9
Rostral barbel	39	38	9.9

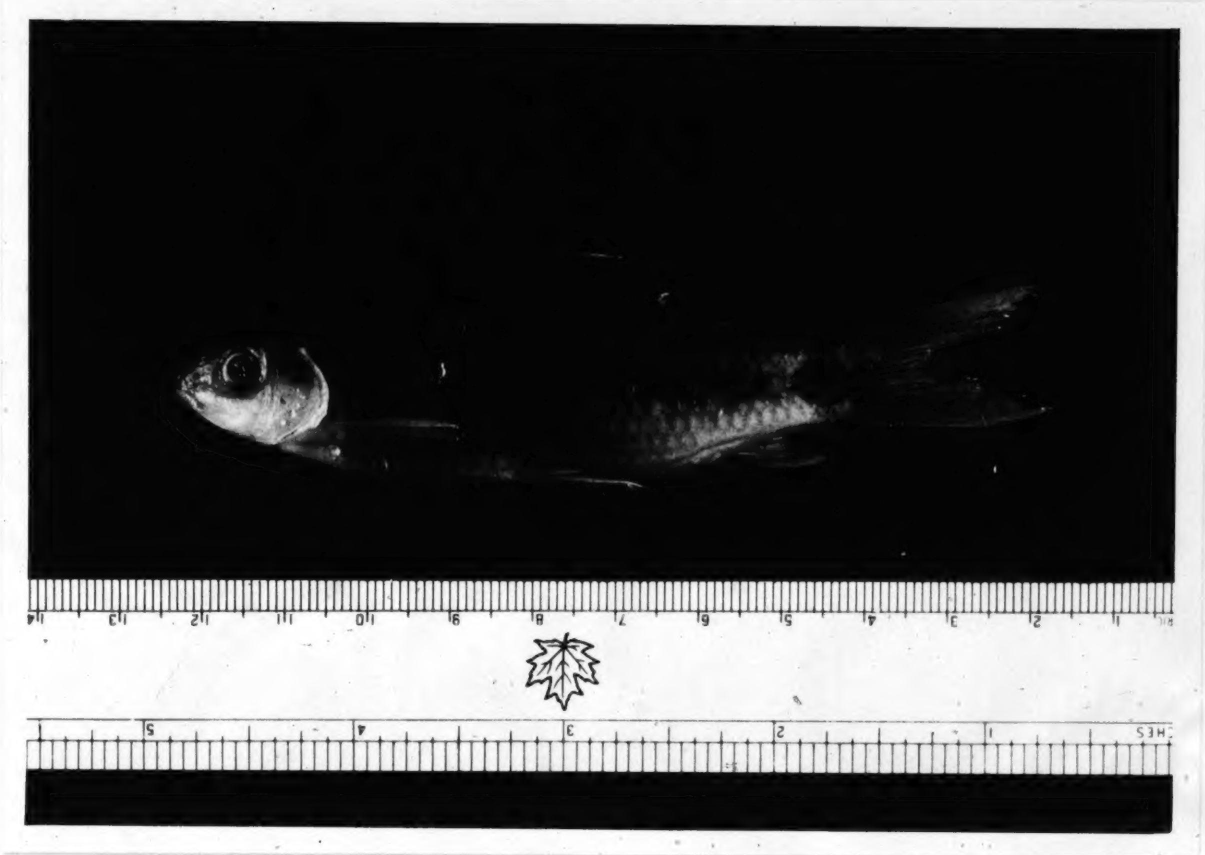

Fig. 9 Osteochilus kahajanensis kahajanensis (Bleeker) KCTR 76-17

Osteochilus kahajanensis chini new subspecies

Osteochilus microcephalus Inger & Chin, 1962: p91, fig 43

Diagnosis

D. IV,12-14; l.l. 31-32; c.f. 11/2/13; c.p. 16

O. kahajanensis chini can be recognized as having 2 tubercles on the snout (one on each side) and a short dorsal fin (branched dorsal rays 12-14 (usually 13). *O. kahajanensis kahajanensis* and *O. kahajanensis chini* can be separated by the number of branched dorsal rays, (*O. kahajanensis kahajanensis* has 15-16, rarely 14) and by the depth of body (320-360 in *O. kahajanensis kahajanensis* and 350-380 in adult *O. kahajanensis chini*). The melanin pigment on the body is also very light in the new subspecies but heavy in the former subspecies.

Description

Body oblong and compressed; depth 350-380 (mean 363) (in thousandths of standard length). Head 207-248 (mean=230); eye 47-63 (mean=54), large fish with relatively small eye. Snout 77-92 (mean=84); with two tubercles in front (one on each side); snout longer than eye diameter in adult fish, shorter than interorbital space, about equal to the postorbital part of the head. Interorbital space slightly convex, 105-131 (mean=121) Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surafce of upper lip consists of well developed long undivided costae. Predorsal length 405-473 (mean=443); origin of dorsal fin opposite 9th (rarely 8th) scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin rather short with normal height, its fourth simple ray shorter than the base of dorsal fin, the length of fourth simple ray 260-303 (mean=283), and the base of dorsal fin 309-371 (mean=333); branched dorsal rays 12-14 (usually 13). The posterior base of dorsal fin opposite 20th -23rd scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from -1 to 1. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th-10th scale of lateral line. Prepelvic length 491-531 (mean=513), pelvic insertion opposite 10th -11th scale of lateral line. Preanal length 742-791 (mean=770); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st-22nd scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 114-152 (mean=136); least depth of caudal peduncle 129-148 (mean=138), longer than half of head length, and surrounded by 16 scale rows. Scales with radii parallel medially and radiating laterally; predorsal scales 9-10 (rarely=11); circumferential scales 11/2/13; transverse scales to the base of pelvic fin 5.5/1/4.5. Lateral line scales 31-32, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 28-41.

Preserved specimens light brown, dorsal of head and back is darker. Diffuse median lateral stripe present in young, faint or absent in adults. Dorsal and caudal fins with dark melanophores on the membrane, other fins plain.

Distribution

The distribution of *O. kahajenenesis chini* is restricted the eastern parts of the State of North Borneo.

Habitat

Turbid streams or rivers.

Etymology

The subspecific name is given for Mr. Chin Khuikong of Department of Agriculture, State of North Borneo, for his efforts to collected these specimens.

Material examined (150 specimens; 49.8–143.9 mm standard length)

Holotype : FMNH 68230; 127.8mm standard length, type
locality: Kinabatangan District, Kinabatangan
River at Deramakot, North Borneo; collected by
R.F. Inger

Paratype : FMNH 68230 (1 spec.) 116.7mm standard length
(same data)

Additional paratype : all from State of North Borneo,
Malaysia.

FMNH 68231 (1 spec.) 143.9 mm; Kinabatangan
District, Deramakot

FMNH 68237 (49 spec.) 50.9–92.0 mm; Kinabatangan
District, Deramakot hill stream.

FMNH 44746 (2 spec.) 100.1–130.2 mm; Lahat Datu
District

FMNH 98239 (1 spec.) 65.4 mm; Kinabatangan
District

FMNH 68236 (1 spec.) 65.8 mm; Kinabatangan
District

FMNH 44740 (1 spec.) 72.2 mm; Kinabatangan
District

FMNH 68235 (1 spec.) 57.5 mm; Kinabatangan
District

FMNH 68233 (1 spec.) 49.8 mm; Kinabatangan
District, Deramakot;

FMNH 44742 (1 spec.) 90.8 mm; Labuk District

FMNH 68229 (50 spec.) 50.6–93.5 mm; Kinabatangan
District; Deramakot, hill stream.

FMNH 68234 (10 spec.) 33.6-65.3.mm; Kinabatangan District

Table 10 Proportional measurements of *O. kahajanensis chini* (measurements expressed as thousandth of standard length)

Characters	type	paratypes (n=49)	
		mean	S.D.(n−1)
Depth	365	362	11.3
Head	219	230	15.6
Eye	48	54	5.9
Snout	86	84	4.5
Interorbital space	124	121	6.4
Base of dorsal fin	334	333	16.9
Fourth simple dorsal ray	284	283	13.8
Predorsal length	422	443	20.4
Prepelvic length	501	513	15.0
Preanal length	756	770	13.5
Third simple anal ray	245	239	7.8
Pectoral fin length	243	239	7.8
Pelvic fin length	261	242	9.9
Depth of caudal peduncle	140	138	5.6
Length of caudal peduncle	114	136	12.2
Lateral line scales	32	31.6	0.5
Predorsal scales	10	10.1	0.7
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	13	13.2	0.4
Pectoral rays	16	15.0	9.9
Gill rakers	38	35.8	3.7
Maxillary barbel	90	84	9.9
Rostral barbel	41	41	4.6

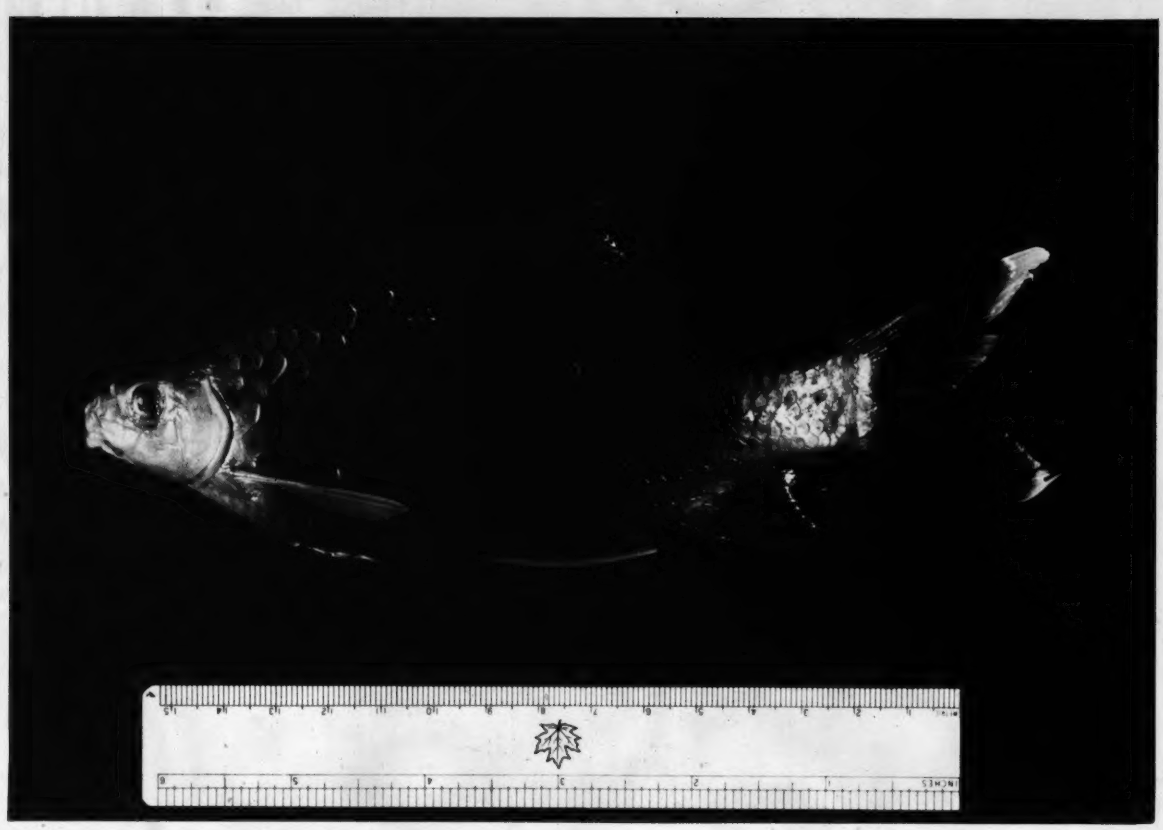

Fig. 10 *Osteochilus* *kahajanensis* *chini* new subspecies Holotype 68230

Osteochilus spilurus (Bleeker)

Dangila spilurus Bleeker, 1851: p.272; original description; type locality: Bandjermassing, Borneo; holotype BMNH 1866.5.2.78, 75 mm total length (given by Bleeker), 61.0 mm standard length (my measurement).

Rohita oligolepis Bleeker, 1853: p.191; original description; type locality: Marawang, Banka; syntype: BMNH 1866.5.2.167, and RMNH 4962, 103 and 100 mm total length (given by Bleeker), 74.3, and 72.0 mm standard length (my measurement).

Dangila spilurus Bleeker, 1860: vol.2,p. 206; description; ....1863: vol.3, p.48; description.

Rohita oligolepis Bleeker, 1860: vol.2, p.185; description; ....1863: vol.3,p.71; description, with color plate.

Osteochilus oligolepis Gunther, 1868: vol.7, p.45; description.

Osteochilus spilurus Gunther, 1868: vol.7, p.45; description.

Osteochilus spilurus Weber & de Beaufort, 1916: vol.3, p.139; description; locality: Sumatra: Taluk, Ringat, and Gunang Sahilan.

Nomenclature

Bleeker described *Dangila spilurus* (1 specimen) in 1851 and *Rohita oligolepis* in 1853 (2 specimens). The *Dangila spilurus* type and one of the *rohita oligolepis* type specimens were purchased by the British Museum. The other type specimen of *Rohita oligolepis* remained in Holland. Gunther (1868) examined both type specimens in BMNH and placed both species under *Osteochilus* but still recognized both as valid species. Weber and de Beaufort (1916) synonymized the two species and recognized *O. spilurus* as the senior synonym. I have examined all the type specimens and I agree with Weber and de Beaufort (1916).

Diagnosis

D. IV,10–111; l.l I 27–29; c.f.9/2/11; c.p. 16

Osteochilus spilurus is the smallest species of *Osteochilus* , with adult specimen rarely exceeding 70 mm in standard length. The lateral line scale count of 27–29 is unique among *Osteochilus*; some scales of the sides have a dark bar, forming an irregular arrangement of small bars on the side of the body. There is a black blotch on the scale immediately above and below the fifth scale of the lateral line.

Circumferential scales 9/2/11 and short dorsal fin (10–11 branched dorsal rays) (shared with *O. branchynopteroides, O. bellus,* and *O. ingeri*). *O. bellus,* and *O. ingeri* have a high gill raker count (40–47, against 28–30) and more lateral line scales (30–31). *O. brachynotopteroides* has 33–34 scales in the lateral line and a more slender body.

Description

Body oblong, deep, and compressed; depth 307–349 (mean=325) (in thousandths of standard length). Head 233–260 (mean=246), eye 51–63 (mean=57), large fish with relatively small eyes. Snout 72–101 (mean=89); entire, without tubercles or pores; snout longer than eye diameter, shorter than interorbital space, usually shorter than the postorbital part of the head. Interorbital space slightly convex, 113–135 (mean=121). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip with well developed, moderately long, undivided, costae. Predorsal length 414–469 (mean=440); origin of dorsal fin opposite 8th scale of lateral line; before mid-point between tip of snout and caudal base and also before the pelvic insertion. Dorsal fin with normal height, its fourth simple ray slightly shorter than the base of dorsal fin, the length of the fourth simple ray 221–275 (mean=250), and the base of dorsal fin 277–308 (mean=295); branched dorsal rays 11–12 (rarely 10). The insertion of the dorsal fin opposite 18th–19th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from one to two (usually one). Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 7th–8th scale of lateral line. Prepelvic length 509–539 (mean=525), pelvic fin insertion opposite 9th–11th scale of lateral line. Preanal length 741–805 (mean=767); anal fin truncate, third simple ray rather weak; anal fin origin opposite 19th–20 th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 106–155 (mean=123); least depth of caudal peduncle 145–156 (mean=150), usually more than half of head length and surrounded by 16 scale rows. Scales with few radii nearly parallel; predorsal scales 8–9 (usually); circumferential scale 9/2/11, transverse scales (to the base of pelvic fin) 4.5/1/4–4.5. Lateral line scale 26–29 (usually 28) with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 25–28.

Preserved specimens are yellowish-brown to dark brown, dorsal part of head and back darker than the body. Dark bar on some of the scales on the side forming an irregular pattern, some specimens with a small black blotch above pectoral fin. Dorsal fin with stripe on the middle portion of the fin membrane, caudal fin dusky, other fins plain.

Distribution

O. spilurus is restricted to the southern range of the genus: southern part of Malay Peninsula, southern Sumatra, western and southern Borneo, Java, Island of Bangka, and Island of Billiton.

Habitat

Small forest streams with swift current, clear or brown tinted.

Material examined (129 specimens ; 20.2–74.4 mm standard length)

Holotype: BMNH 1866.5.2.78; Bandjermassing, Borneo

Syntype of *Rohita oligolepis*

: BMNH 1866: 5: 2: 167; Marawang, Bangka

: RMNH 4962; Marawang Banka

Other specimens:

: BMNH 1938.12.1.105-6 (2 spec.), Mawai District, Johore, Ma;aysia

: NMS 1887, coll. Mawai District, Johore, Malaysia

: ZMA no ca. no. (6 spec.); Biliton (or Belitung)

: ZMA 116.093 (1 spec.); Ringgat, Sumatra

: ZMA 116.096 (4 spec.); Taluk, Sumatra

: ZMA 116.095 (6 spec.); Gunung Sahilan, Sumatra

: ZMA 116.101 (4 spec.); Djember Sungei, Legi, Java

: NMNH 101208 (4 spec.); Ayer Hitam, Johore, Malaysia

: KCTR 76-46 (27 spec.); Sungai Gentu flows into Kapuas mainstream, 55 km, N.E. of Sintang, Borneo.

: KCTR 76-42 (46 spec.); Sungai Sering, forested tributary of Sungai Palin, 5-10 m wide and 2 m. deep, 37 km W. of Putussibau, 3-5 km up Sungai Palin from Kapuas mainstream; Borneo

: KCTR 76-16 (3 spec.) Sungai Tekam, small forest stream where it enters right side of Kapuas main stream about 5-6 km from Sanggau; Borneo

: CAS 31985 (3 spec.) Malaysia

: CAS 31181 (6 spec.with 1 *O. hasselti*) Johore Malaysia

: CAS 34756 (14 spec) Malaysia

Table 1.1 Proportional measurements of *O. spilurus* (measurements expressed as thousandths of standard length)

Characters	type	other specimens	
		mean	S.D.(n=128)
Depth	274	325	13.3
Head	234	246	9.1
Eye	61	57	3.1
Snout	74	89	8.7
Interorbital space	102	121	6.9
Base of dorsal fin	228	295	9.6
Fourth simple dorsal ray		250	15.4
Predorsal length	452	440	16.4
Prepelvic length	530	525	11.5
Preanal length	796	767	17.3
Third simple anal ray		202	10.4
Pectoral fin length		199	13.1
Pelvic fin length	170	209	10.8
Depth of caudal peduncle	128	150	3.5
Length of caudal peduncle	111	123	15.1
Lateral line scales	28	27.7	0.8
Predorsal scales	9	8.7	0.5
Circumferential scales	9/2/11	9/2/11	
Transverse scales (to the base of pelvic fin)	4.5/1/4	4.5/1/4	
Circumpeduncular scales	16	16	

Dorsal branched rays	10	11.4	0.7
Pectoral rays		13.5	0.5
Gill rakers		27.2	1.3
Maxillary barbel	87	109	7.5
Rostral barbel	49	59	6.5

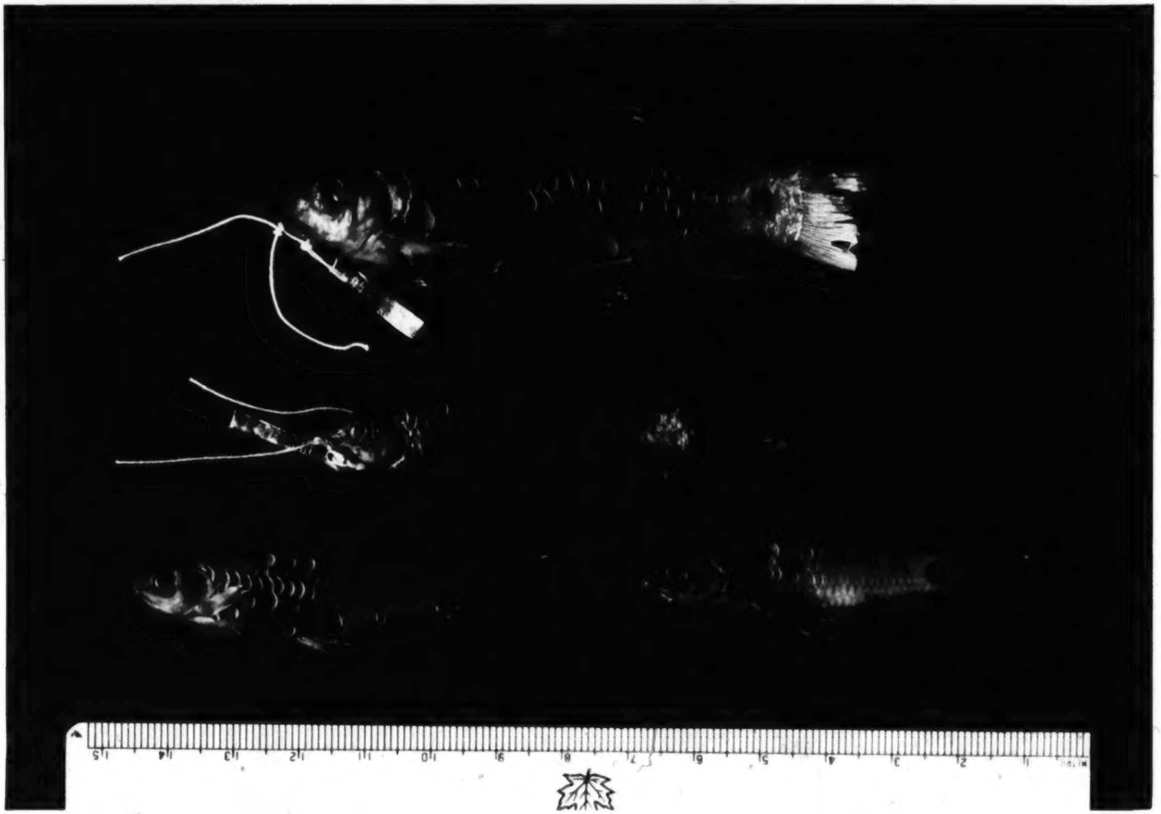

Fig. 11 Osteochilus spilurus (Bleeker) Above(2) CAS 31181

Below(2) KCTR 76-46

Osteochilus ingeri new species

Osteochilus spilurus Inger and Chin, 1962: p 90

Diagnosis

D. IV,11-12; l.l. 30-31; c.f.9/2/11; c.p. 16

Osteochilus ingeri is unique and easy to recognize. It has a dark rectangular bar in the pocket of each scale forming a reticulated pattern on the body. Gill rakers on the first gill arch 40-45, upper labial fold with long undivided costae.

It shares a circumferential scale number of 9/2/11 with a few species such as: *O. spilurus, O. bellus,* and *O. brachinotyperoides*, but the reticulated pattern on the body stated above is unique to *O. ingeri*. *O. spilurus* is the most closely related species, and it has fewer lateral lines scales (27-29), fewer gill rakers (28-30), and is very small in size (specimens exceeding 70 mm are rare, but *O. ingeri* are well over 100 mm). *O. bellus* differs from *O. ingeri* by having tubercles on the snout and a different pattern of spots on the body (see description of *O. bellus,* page 64).
O. brachynotopteroides has a long slender body (oblong in *O. ingeri*), fewer gill rakers (31), and a plain body.

Description

Body oblong, and slightly compressed, depth 286-364 (mean=325) (in thousandths of standard length). Head 195-243 (mean=214); eye 38-54 (mean=46); large fish with relatively small eye. Snout 67-96 (mean=83); entire, without tubercles or pores; snout longer than eye diameter in adult fish, shorter than interorbital space. Interorbital space slightly convex, 101-129 (mean=115). Mouth inferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed, long, undivided, costae. Predorsal length 383-472 (mean=432); origin of dorsal fin opposite 9th-10th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin somewhat falcate, its fourth simple ray about equal to or longer than the base of dorsal fin, length of fourth simple ray 261-343 (mean=298), and the base of dorsal fin 221-291 (mean=264); branched dorsal rays 10-11 (rarely 12). The insertion of the dorsal fin is opposite 18th-19th scale of the lateral line, number of scale from insertion of the dorsal fin to vertical from anal fin origin varies from one to two (usually two). Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th-10th scale of lateral line. Prepelvic length 463-529 (mean=497); pelvic fin insertion opposite 11th scale of lateral line. Preanal length 733-779 (mean=749); anal fin concave, third simple ray rather weak; anal fin origin opposite 20th-21st scale of lateral line. Caudal fin deeply forked. Its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 135-167 (mean=148), least depth of caudal peduncle 123-149 (mean=136), longer than half of head length, and surrounded by 16 scale rows. Scales with radii parallel medially and radiating laterally; predorsal scales 9-10 (rarely 11); circumferential scales 9/2/11-12 (rarely 11/2/11-12); tranverse scales to the base of pelvic fin 4.5/1/3.5 (rarely 5.5/1/3.5). Lateral line scales 30-31, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 40-43.

Preserved specimens olive brown above, lighter below, the dorsal region of the head and the back are darker. At the pocket of each scale is a vertical rectangular bar forming a reticulated or checkered pattern on the body; a large round black spot on the caudal peduncle. Membrane of dorsal fin dark; other fins plain. According to Inger & Chin (1962), live specimens have red spots on the anterior scales.

Distribution

O. ingeri is an endemic species to eastern North Borneo. It can be found in the following area: Kinabatangan District, Lahat Datu District, and Tawau District, Kalabakam.

Habitat

According to Inger & Chin (1962), this species is found in small clear streams having sand and gravel bottoms which are covered with dead leaves in the quiet pools.

Discussion

Specimens of this species were collected by Dr,R.F. Inger of Field Museum of Natural History in a Borneo Zoological Expedition (1950 and 1956). The species was identified as *O.spilurus* and was published as such in "The fresh-water fishes of North Borneo" by Inger and Chin (1962). However, there are various characters that differ from *O. spilurus* and the species is apparently an undescribed one.

Etymology

The specific name of this species is in honor of Dr. Rober F. Inger (of the Field Museum of Natural History) who collected the type specimens.

Material Examined (108 specimens, 8.6–127 mm standard length)
Holotype: FMNH 68540; 111.8 mm standard length

Paratypes: FMNH 68540 (21 spec.); 88.4–121.9 mm
standard length type locality: Sungai Tawan,
Kalabagan Tawau District, North Borneo.
Collected in June 6, 1956 by Dr.R.F. Inger

Additional paratypes
FMNH 51607 (50 spec.); 8.6–127.3 mm; East
coast Residency, Kinabatangan District,
North Borneo.
FMNH 51606 (17 spec.); 84.3–103.0 mm; East
coast Residency, Kinabatagan District,

North Borneo.

FMNH 44739 (4 spec.); 96.2–114.7 mm; Lahad
Datu District, North Borneo.

FMNH 68541 (15 spec.); –111.5 mm; Sungai
Tawau, Kalabatangan, Tawai District,
North Borneo.

CAS 32814 (1 spec.); 79.1 mm; North Borneo.

Table 12 Proportional measurements of *O. ingeri* (measurements expressed as thousandths of standard length)

Characters	holotype	paratypes(n=108)	
		mean	S.D.(n−1)
Depth	335	325	14.8
Head	215	214	12.6
Eye	48	46	4.6
Snout	72	83	6.4
Interorbital space	111	115	7.0
Base of dorsal fin	261	264	12.5
Fourth simple dorsal ray	261	298	15.5
Predorsal length	436	432	17.0
Prepelvic length	496	497	14.4
Preanal length	760	749	35.0
Third simple anal ray	211	233	9.5
Pectoral fin length	222	233	14.2
Pelvic fin length	239	248	9.5
Depth of caudal peduncle	140	136	5.0
Length of caudal peduncle	138	148	7.9
Lateral line scales	31	29−31	
Predorsal scales	10	9.7	0.05
Circumferential scales	9/2/11	9/2/11	
Transverse scales (to the base of pelvic fin)	4.5/1/3.5	4.5/1/3.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	11	11	0.4
Pectoral rays	16	14–16	
Gill rakers	41	39.9	2.3
Maxillary barbel	76	73	7.5
Rostral barbel	47	44	4.7

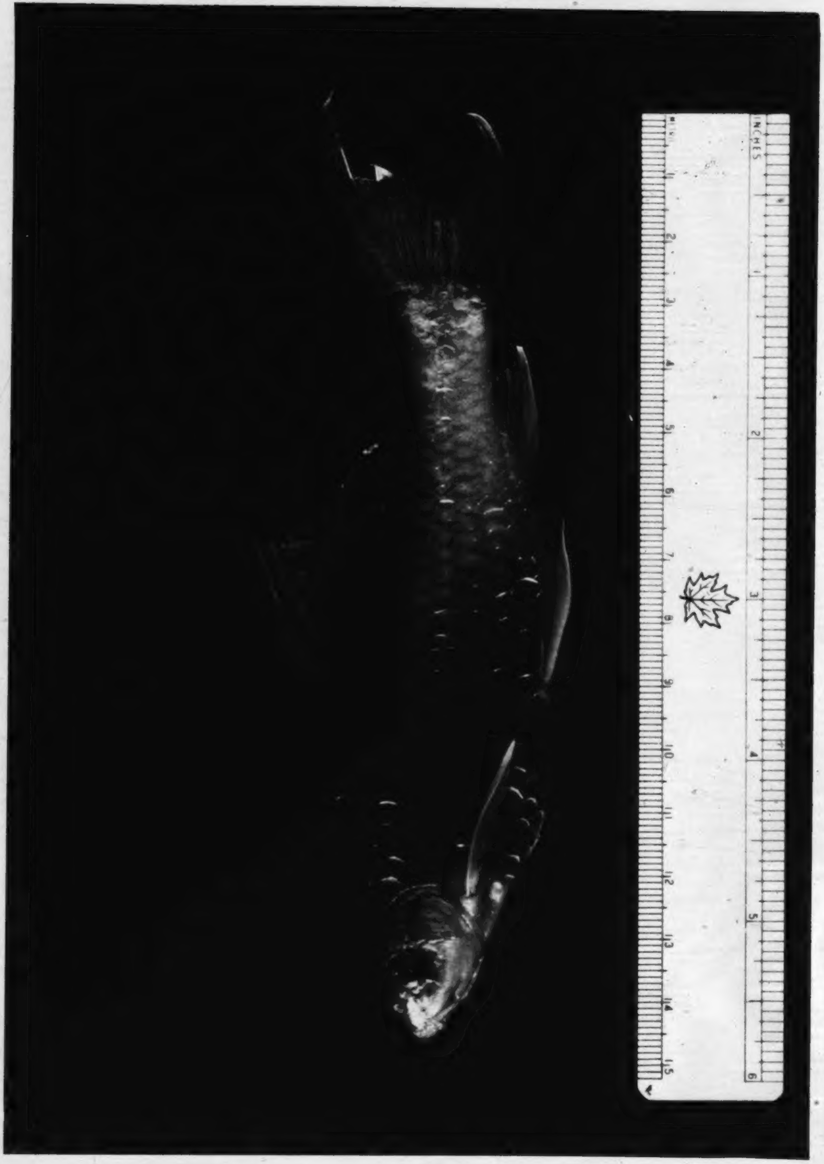

Fig. 12 Osteochilus ingeri new species Holotype

Osteochilus triporus Bleeker

Rohita triporus Bleeker (not *O. triporus*), 1852: p.598; original description; type locality: Sumatra (Palembang); type of Bleeker (1952) BMNH 1866.5.2.164; 130 mm. total length (given by Bleeker), 94.5 mm. standard length (my measurement).

,*Rohita (Rohita) triporus* Bleeker, 1863: vol.3, p.70; description locality: Sumatra (Palembang), Borneo (Pontianak); neotype RMNH 4963; with color plate.

Osteochilus triporus Gunther, 1868: p.44; description (based on Bleeker's 1852 specimen).

Osteochilus triporus Weber & de Beaufort, 1916: Vol.3, p.133; description, locality: Sumatra (Djambi).

Nomenclature

Bleeker (1852) described the species from a single specimen from Palembang, Sumatra (130 mm. TL). Gunther (1868) claimed that specimen no. BMNH 1866.5.2.164 is the holotype. My measurements and counts of this specimen agree with Bleeker's description, except that the coloration was not recognizable as the fish was not well preserved. Based on Bleeker's original description, the specimen had a diffuse longitudinal median lateral stripe from the head to the caudal fin. When Bleeker published his Atlas in 1863, he redescribed *O. triporus* in vol.3 p.70 with one additional specimen (TL 154 mm) from Borneo (Pontianak) (RMNH 4963). The description is based on both specimens but the illustration is based on the second specimen. In describing the coloration he indicated that there were rows of spots on the body as well as a spot near the origin of the dorsal fin which he did not mention in the original description; he also mentioned that the median lateral stripe is more distinct in the smaller specimen (the first specimen). I presume that the new characters (rows of spots on body and the dark spot near the origin of dorsal fin) were based on the second specimen only. From my examination of these two specimens. I feel that they are certainly different species, the first specimen belonging to *O. microcephalus* (Cur. & val.) and the second specimen representing the *O. triporus* recognized by most ichthyologists, based on Bleeker's illustration (1863). Rather than make *O. triporus* a junior synonym of *O. microcephalus* and adopt a new name for a species will known as *O. triporus*, I intend to suppress the original type (BMNH 1866.5.2.164) and designate the specimen no.RMNH 4963 as a neotype of *O. triporus* (Bleeker).

Weber & de Beaufort (1916) felt that *O. triporus* agreed quite well with the description of *O. vittatus* (=microcephalus) and he described *O. intermedius* on the basis of one character which distinguishes it from *O. triporus* (c.f 11/2/11 in *O. triporus* and 9/2/13 in *O. intermedius*). Hardenberg (1936) stated that *O. triporus* is different from *O. vittatus*, but felt that the difference between *O. triporus* and *O. intermedius*, as described by Weber & de Beaufort, was very small and probably only variation within the species. In studying these two forms I have found that there are many characters that separate them, and they are different species as stated here in the diagnosis.

Diagnosis

D. IV,11–12; l.l. 29–30; c.f 11/2/11–13; c.p. 16

Osteochilus triporus has a distinct large black spot near the origin of the dorsal fin and rows of spots along side of the body which are usually less distinct on the upper half of the body than the lower half. Circumferential scales usually 11/2/11 (rarely 11/2/13). Mouth subinferior, ventral part of upper lip with long costae which are divided into two or three portions. Gill rakers on the first gill arch 27–32.

Osteochilus triporus shares many characters with *O. intermedius* such as the black spot on the dorsal fin and the rows of spots on the body; it also shares some characters with *O. microcephalus* such as three tubercles on snout, branched dorsal rays, and rows of partially developed spots in some specimens (but there is a median lateral stripe on the side of body which may be faded after death or long preservation as in *O. microcephalus*). *O. microcephalus* also has more lateral line scales (32–33) (29–31 in *O. triporus*). *O. intermedius* is separated from *O. triporus* by having 13–14 branched dorsal rays, 37–50 gill rakers on the first gill arch, no tubercles on the snout, circumferential scales 9/2/13, and long undivided costae on the ventral part of the upper lip.

Description

Body oblong, slender, and compressed, depth 257-349 (mean=295) (in thousandths of standard length). Head 217-282 (mean=239); eye 49-81 (mean=59), larger fish with relatively small eye. Snout 64-99 (mean=85); usually with three pointed tubercles in the front, the middle one is the largest and the lateral ones are small or rudimentary; snout longer than eye diameter in adult fish, shorter than interobital space, about equal to the postorbital part of the head. Interorbital space slightly convex, 91-114 (mean=108). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels usually shorter than the maxillary one. Ventral surface of upper lip consists of well developed moderately long costae, most of which are divided into two or three unequally portions. Predorsal length 404-474 (mean=440); origin of dorsal fin opposite 8th-9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually falcate, its fourth simple ray usually greatly produced, longer than the base of dorsal fin, the length of the fourth simple ray 241-366 (mean=300), and the base of dorsal fin 238-333 (mean=252); branched dorsal rays 11-12. The insertion of the dorsal fin is opposite 18th-20th scale of lateral line, number of scales from insertion of dorsal fin to vertical from anal fin origin varies from one to three. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 8th-9th scale of lateral line. Prepelvic length 453-537 (mean=502); pelvic fin insertion opposite 10th-11th scale of lateral line. Preanal length 760-793 (mean=771); anal fin concave, third simple ray rather weak; anal fin origin opposite 20th-22th scales of lateral line. Caudal fin deeply forked, its lobe more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 105-156 (mean=127); least depth of caudal peduncle 117-137 (mean=123), usually less than half of head length and surrounded by 16 scale rows Scales with nearly parallel longitudinal radii, predorsal scales usually 10 (rarely 9); circumferential scales 11/2/11 (rarely 11/2/13) and 4.5/1/3.5-4 in transverse series to the base of the pelvic fin; lateral line scales 29-31 with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 27-32.

Preserved specimens are dusky on the upper two fifths of the side, the dorsal part of head and back darker. Anterior portion of dorsal fin with a large black spot near the base; a dark stripe along the mid-portion of the fin membrane behind the large black spot. Posterior margin of dorsal fin dark, other fins clear. The rows of spots present along side of the body, at the basal pocket of each scale, are usually more distinct on lower half of the body. In fresh or live specimens the side is gray with a bluish-green hue, under part whitish silver. Dorsal fin densely pigmented with dark melanophores forming pattern as stated above, other fins pinkish and plain.

Distribution

The distribution of *O. triporus* is limited. There is only one record from eastern Sumatra, but it is possible that they are widespread in this poorly collected area. It is quite common in western Borneo (Kapuas Basin). It may occur in Malaysia as reported by Herre & Myers (1937) from Ayer Hitam, Johore. Tirant (1929) reported this species from Hue, Vietnam (I have not seen the specimen). The number of lateral line scales (34) given by Tirant is more likely to be that of *O. microcephalus* than *O. triporus*.

Habitat

Small or large streams at low altitudes, current swift, water clear; bottom brown or dark brown, sandy or pebbled, ph 5.5-6.5.

Material Examined (21 specimens, 44.7-118.8 mm standard length).

Neotype: RMNH 4960, Pontianak, Borneo

Other specimens:

Sumatra: ZMA 116.080 (2 spec.) Gunung Sahilan

Borneo: MHNP 85-177-40-1 (2 spec.) no specific locality
(one specimen belongs to *O. intermedius*)
: KCTR 76-42 (6 spec.), Sungai Seriang tributary
of Kapuas.
: KCTR 76-19 (6 spec.), Sintang Market.
: KCTR 76-20 (4 spec.), Sungai Kabian,
tributary of Kapuas.

Table 13 Proportional Measurements of *O. triporus* (measurements expressed as thousandths of standard length)

Characters	type	other specimens	
		mean	S.D.(n=21)
Depth	330	295	29.5
Head	219	239	16.5
Eye	53	59	8.9
Snout	64	85	7.1
Interorbital	112	108	7.3
Base of dorsal fin	291	251	75.1
Fourth simple dorsal ray	366	251	49.7
Predorsal length	429	440	15.3
Prepelvic length	509	502	28.5
Preanal length	771	771	20.7
Anal fin height	206	206	10.8
Pelvic fin length	244	232	21.1
Pectoral fin length	227	218	21.8
Depth of caudal peduncle	134	123	6.2
Length of caudal penduncle	126	127	10.7
Lateral line scales	30	30.2	0.4
Predorsal scales	10	10	0.5
Circumferential scales			
Transverse scales			
Circumpeduncular scales	16	16	
Dorsal branched rays	12	11.7	0.5

Pectoral rays	16	15.4	0.7
Gill rakers	28	29	1.8
Maxillary barbels	36	68	11.4
Rostral barbels	15	36	9.0

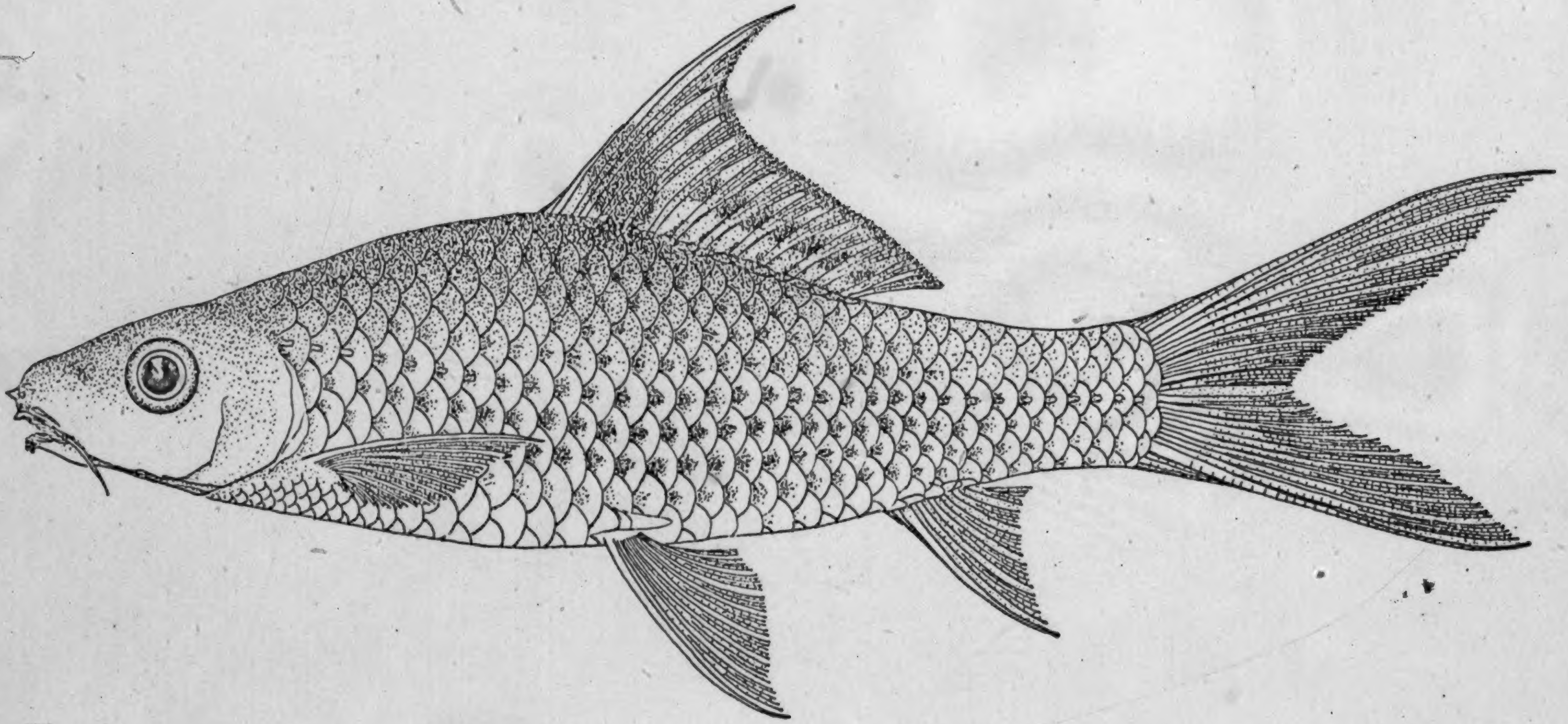

Fig. 13 *Osteochilus triporus* (Bleeker) KCTR 76-42, 84.8 mm SL

Osteochilus intermedius Weber and de Beaufort

Osteochilus intermedius Weber & de Beaufort, 1916: vol.3, p.113-34; original description; type locality: Sumatra (Djambi); syntype: 9 specimens, ZMA 112.610 (8 spec.) standard length 61.8-99.3 mm.; AMNH 9289 (1 spec.) 82.0 mm. standard length.

Osteochilus intermedius Hardenberg, 1936: p.237; description: locality: middle course of Kapuas (Borneo).

Nomenclature

Weber and de Beaufort were not sure about the validity of this species when they described it in 1916. They gave a very poor description. In comparing it with *O. triporus,* they stated that the two differed by only one transverse scale and by the presence and absence of black bands on the outer upper and lower margins of the caudal fin. Hardenberg (1936) felt that *O. intermedius* might be only a variety of *O. triporus.* In studying these two forms I have found that there are many characters that separate them and confirm the validity of this species.

Diagnosis

D. IV,13-14; l.l 30-32; c.f. 9/2/13; c.p. 16.

Osteochilus intermedius has a distinct large black spot near the origin of the dorsal fin; and rows of spots along the side of the body, which are usually distinct on the lower part of the body. Mouth subinferior, ventral part of upper labial undivided costae, gill rakers on the first gill arch 39-49.

O. intermedius share many characters with *O. triporus* as stated above. The differences between these two species were indicated previously in the diagnosis of *O. triporus* on page 100

Description

Body oblong, slender and compressed, depth 266–394 (mean=330) in thousandths of standard length). Head 221–286 (mean=251); eye 48–72 (mean=66), large fish with relatively small eye. Snout 71–99 (mean=87); entire, no tubercles on the front; snout longer than eye diameter in adult fish, shorter than interorbital space, about equal to postorbital part of the head. Interorbital space slightly convex, 103–128 (mean=115). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels usually shorter than the maxillary ones. Ventral surface of upper lip consists of well developed, moderately long, undivided costae. Predorsal length 440–480 (mean=447); origin of dorsal fin opposite 8th–9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually of normal height, its fourth simple ray shorter than the base of dorsal fin, the length of the fourth simple ray 223–277 (mean=252), and the base of dorsal fin 310–381 (mean=334); branched dorsal rays 13–15 (usually 14). The insertion of the dorsal fin opposite 21st–22nd scales of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from zero to one. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th–10th scale of lateral line. Prepelvic length 520–564 (mean=541); pelvic fin insertion opposite 11th scale of lateral line. Preanal length 787–815 (mean=796); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st–23rd scales of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 102–141 (mean=131), usually about half of head length, and surrounded by 16 scale rows. Scales with relatively few radii radiating from the center, predorsal scales usually nine (rarely eight), circumferential scales 9/2/13 (4.5/1/4–4.5 in transverse series to the base of pelvic fin); lateral line scales 31 (rarely 30), with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 35–49.

Preserved specimens are dusky on the top two-fifths of the body; the dorsal part of head and back are darker. Anterior portion of dorsal fin with a large black spot near the base; a dark stripe along the mid-portion of the fin membrane behind the large black spot. Caudal fin with a diffuse black longitudinal band on the outer upper and lower margin of the fin lobe, the band on the lower lobe usually more distinct. Other fin transparant and plain. Six rows of spots present along side of the body, one on lateral line, three below, and two above; the four middle rows are more distinct than the out Each spot of the rows formed in a scale pocket is more distinct on the lower half of the body than on the upper (the spots may disappear in specimens preserved for a long time). Coloration of fresh or live specimens unknown.

Distribution

Only known from two localities: Kapuas River, Borneo and Batan Hari River at Djambi, Sumatra.

Habitat

Small or large forest streams; current swift; clear water, with brown tint; PH 6.0-6.5 (according to collecting data of Dr.Tyson Roberts).

Material Examined (20 specimens, 47.4- 154.0 mm in standard length)

Syntype:ZMA 112.609 (8 spec.) Batang Hari River, Djambi
Sumatra.
:AMNH 9289 (1 spec.) Batang Hari River, Djambi, Sumatra.

Other specimens:

Borneo: ZMA 112.610 (2 spec.) Kapuas River at Tutus Sibau
: KCTR 76.42 (3 spec.) Sungai Seriang, 37 km West of
Putussibau
: KCTR 76-43 (1 spec.) small oxbow lake cut off from

Kapuas 124 km NE of Sintang.

: KCTR 76-47 (1 spec.) small forest stream flowing to Kapuas NE of Gunung Setunggul, 53 km NW of Sintang.

: KCTR 76-43 (3 spec.) small oxbow lake complete cut off from Kapuas Mainstream opposite Empangau, 124 km NE of Sintang.

No locality

: MHNP 95-177-40-1 (1 spec.) mix with 2 spec. of *O.triporus*).

Table 14 Proportional Measurements of *O. intermedius* (measurements expressed as thousandths of standard length)

Characters	All Specimens (n=20)	
	mean	S.D.(n−1)
Depth	330	30.8
Head	251	19.1
Eye	66	9.8
Snout	87	7.8
Interorbital	115	5.6
Base of dorsal fin length	334	20.4
Fourth simple dorsal ray	252	13.8
Predorsal length	447	15.9
Prepelvic length	541	15.5
Preanal length	795	13.6
Anal fin height	209	11.2
Pelvic fin length	217	11.4
Pectoral fin length	218	11.6
Depth of caudal peduncle	131	6.1
Length of caudal penduncle	127	11.8
Lateral line scales	30.9	0.4
Predorsal scales	18.9	0.3
Circumferential scales	9/1/13	
Transverse scales	4.5/1/4.5	
Circumpeduncular scales 16		
Dorsal branched rays	13.9	0.4

Pectoral rays	14.3	0.7
Gill rakers	41.0	3.8
Maxillary barbels	85	11.5
Rostral barbels	43	5.7

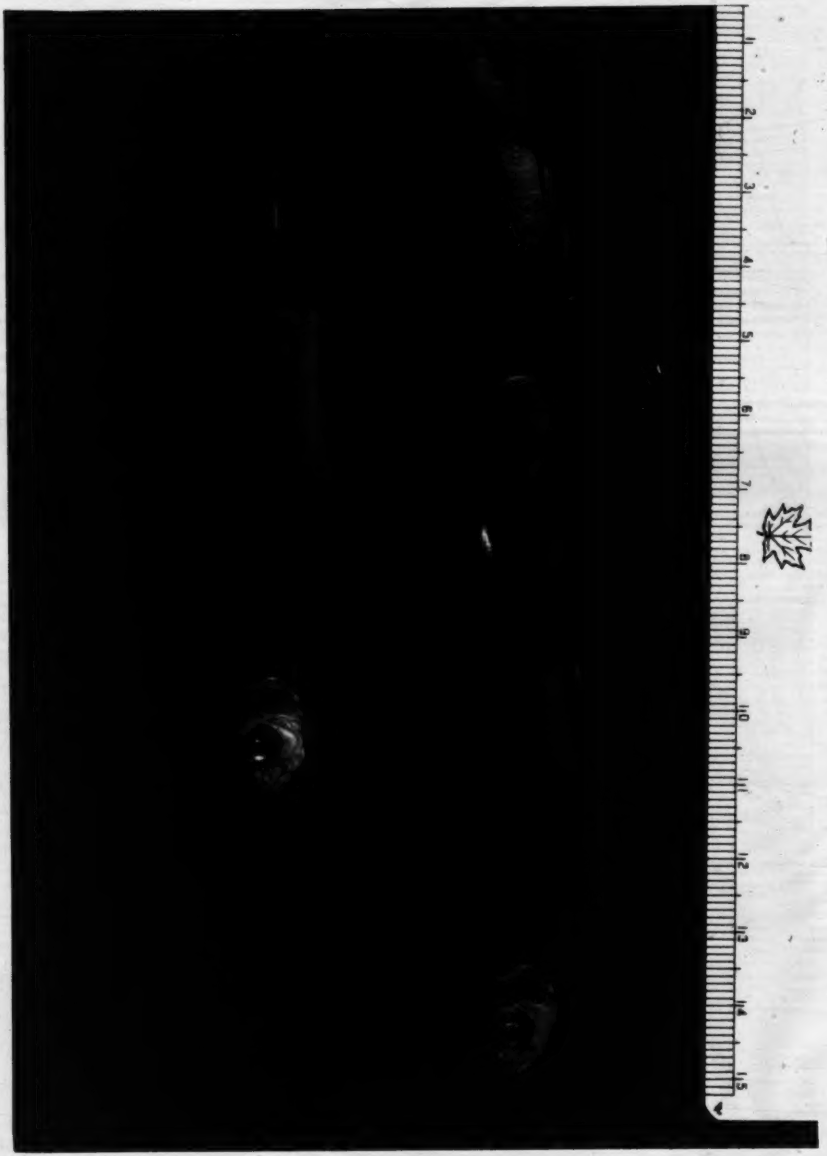
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Fig. 14 Osteochilus intermedius Weber & de Beaufort KCTR above 76-42

below (left) 76-42 (right) 76-47

Osteochilus sarawakensis new species

Osteochilus vittatus Inger & Chin, 1962: p.93-94

Diagnosis

D. IV,11-13; l.l 31-33; c.f. 11/2/13; c.p. 16

Osteochilus sarawakensis has 5-8 (5-6 distinct) rows of spots on the posterior two thirds of the body. In large specimens the spots may form longitudinal stripes. Dorsal fin with 12-13 (rarely 11) branched rays; 32-33 scales on lateral line. Snout entire without tubercles or pores; gill rakers on the first gill arch 26-34.

O. sarawakensis and *O. harrisoni* share many features such as the body form and longitudinal stripes. *O. harrisoni* has about 9-10 longitudinal stripes on the body which are extended from the back of the head to the caudal peduncle and the stripes are more distinct than in *O. sarawakensis*. *O. harrisoni* also has 15-16 branched dorsal rays while *O. sarawakensis* has only 12-13.

Description

Body oblong, and slightly compressed, depth 253-340 (mean=295) (in thousanths of standard length); eye 39-68 (mean=51), large fish with relatively small eye. Snout 71-101 (mean=85), entire, without tubercles or pores; snouts longer than eye diameter in adult fish, slightly shorter than interorbital space, about equal to postorbital part of the head. Interorbital space slightly convex, 92-114 (mean=100). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed moderately long undivided costae. Predorsal length 415-474 (mean=446); origin of dorsal fin opposite 9th-10th scale of lateral line; before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin with normal height, its fourth simple ray slightly shorter than the base of dorsal fin, the length of the fourth simple ray 214-277 (mean=247), and the base of dorsal fin 238-297 (mean=273); branched dorsal rays 12-13 (rarely 11). The posterior base of dorsal fin opposite 20th-21st scale of lateral line, number of scales from posterior base of dorsal fin to vertical from anal fin origin varies from one to three. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th-10th scale of lateral line. Prepelvic length 481-555 (mean=515), pelvic fin insertion opposite 12th (rarely 11th) scale of lateral line. Preanal length 729-796 (mean=762); anal fin concave, third simple ray rather weak; anal fin origin opposite 22nd-23rd scale of lateral line. Caudal fin deeply forked; its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 126-177 (mean=144); least depth of caudal peduncle 118-143 (mean=129), usually more than half of head length, and surrounded by 16 scale rows. Scales with nearly parallel radii, predorsal scales usually 11 (rarely 10); circumferential scales 11/2/13; transverse scales to the base of pelvic fin is 5.5/1/4.4. Lateral line scale usually 32 (rarely 31 or 33), with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 26-34 (mean=31.8).

Preserved specimens are dark brown on the upper two-fifths of the side, the dorsal part of head and back are darker. About eight (5-6 distinct) longitudinal dark stripes or rows of spots formed in each scale pocket, the stripes more intense on posterior two-thirds of the body, and the stripe on the lateral line more distinct than the others. A large black blotch occurs on the caudal peduncle; the dorsal fin membrane is dusky, other fins are hyaline. Coloration of fresh or live specimens unknown.

Distribution

O. sarawakensis is restricted to mountainous areas of Sarawak and of the western part of the state of North Borneo (Malaysia),

Habitat

Forest streams with clear water and swift current (persv. comm. Dr. R. F. Inger).

Discussion

Most of the specimens of this species used in this study are from The Field Museum of Natural History in Chicago and were collected from Sarawak and North Borneo. The specimens were identified as *Osteochilus vittatus* and were used for the account of that species in Inger & Chin (1962) "The Fresh-Water Fishes of North Borneo." Some specimens that I examined in the British Museum are identified as *O. vittatus* or as *O. hasselti* (see description of *O. vittatus* and *O. haselti*). This species is also similar to the sympatric *O. harrisoni* Fowler. There are slight differences in the color pattern on the body but these characters are not very useful since there is a variation with the age of the fish. The major character that I used to separate *O. sarawakensis* from *O. harrisoni* is the number of branched dorsal rays. I have examined more than 150 specimens of *O. sarawakensis* and found a variation of only 11 to 13 branched dorsal rays. Unfortunately there were only two specimens of *O. harrisoni* available for the study and they have 16 and 15 branched dorsal rays which in my opinion is different enough to separate them into two species because (from my study) no single species had as much variation in the number of branched dorsal rays (except the allopatric form of *O. kahajanensis* and *O. hasselti*).

Etymology name after the only known area of occurrence.

Material Examined (160 specimens, 20.1 mm-138.5mm standard length)

Holotype, FMNH.... (1) 138.5 mm in standard length, and **paratopotypes** FMNH.... (49 spec.) 23.5 mm-126.5mm.; type locality; Sungai Putai, branch of Baleh River, Sarawak 3rd Division (Borneo Malaysia); Collected by Dr. R. F. Inger, August 8, 1956.

Additional paratype

FMNH 68530 (20 spec.) 20.1 mm-116.0 mm; Baleh River tributary between Sungai Entunau and Sungai Putai, Sarawak 3rd Division.

FMNH 68908 (7 spec.) 42.0 mm–80.7 mm; Mengiong River, Rapit District, Sarawak 3rd Division.

FMNH 68906 (5 spec.) 67.5 mm–73.5 mm; tributary of Baleh River, Sarawak 3rd Division, about 1000 feet above sea level.

FMNH 68892 (7 spec.); 40.4 mm–70.4 mm; Kapit District, Sarawak 3rd Division.

FMNH 44737 (2); 88.0 mm–124.6 mm; Kota Belud District; State of North Borneo

FMNH 68531 (1 spec.); 135.5 mm; Baleh River, Sungai Dapu, Sarawak 3rd Division.

FMNH 68537 (1 pec.); 76.8 mm; Baleh River near Sungai Arau; Sarawak 3rd Division, about 600 feet above sea level.

FMNH 68912 (1 spec.); 93.2 mm.; Mengiong River, Nanga Takalit camp, Kapit District, Sarawak 3rd Division.

FMNH 68882 (1 spec.); 103.2 mm; Mengiong River, Sarawak 3rd Division.

FMNH 68534 (1 spec.); 75.2 mm; Baleh River, Sungai Putai, Sarawak 3rd Division.

FMNH 68539 (1 spec.); 51.5 mm; Meligon Akah at 1000ft above sea level; Sarawk 4th Division.

FMNH 68536 (1 spec.); 47.5 mm, 81.0 mm; Sungai Bunoh near Sungai Balang at 1,000ft. above sea level, Sarawk 3rd Division.

FMNH 68535 (2 spec.); 93.0 mm., 70.8 mm.; Upper Balch and pool near Sungai Menuang, Sarawak 3rd Division.

FMNH 68534 (2 spec.); 76.0 mm., 77.0 mm; Baleh River, Sungai Putai Camp. Sarawak 3rd Division.

BMNH 1915.3.25.4 (1 spec.); 129.8 mm; Baram River, Sarawak 4th Division.

BMNH 1893.3.6.223-6 (4 spec.); 105.8 mm–119.6 mm.; Merabah, State of North Borneo.

BMNH 1892.9.2.31 (1 spec.); 55.6 mm; Baram River, Sarawak 4th Division.

BMNH 1895.7.2.78 (1 spec.); 99.7 mm.; Pata River.

Table 15 Proportional Measurements of *O. sarawakensis* (measurements expressed as thousandths of standard length)

Characters	holotype	paratypes(n=159)	
		mean	S.D.(n-1)
Depth	290	295	15.0
Head	199	222	15.7
Eye	41	51	8.0
Snout	80	85	7.5
Interorbital	98	100	4.1
Base of dorsal fin	277	273	9.3
Forth simple dorsal ray	238	247	23.1
Predorsal length	421	446	19.2
Prepelvic length	481	515	16.2
Preanal length	742	762	14.0
Anal fin height	206	215	8.5
Pelvic fin length	212	212	9.3
Pectoral fin length	188	204	9.5
Depth of caudal peduncle	127	129	4.4
Length of caudal penduncle	156	144	10.6
Lateral line scales	32	32.1	0.5
Predorsal scales	11	10.8	0.4
Circumferential scales			
Transverse scales			
Circumpeduncular scales	16	16	
Dorsal branched rays	12	12.1	0.5

Pectoral rays	15	14.4	0.5
Gill rakers	36	31.8	3.2
Maxillary barbels	56	71	10.3
Rostral barbels	32	35	5.4

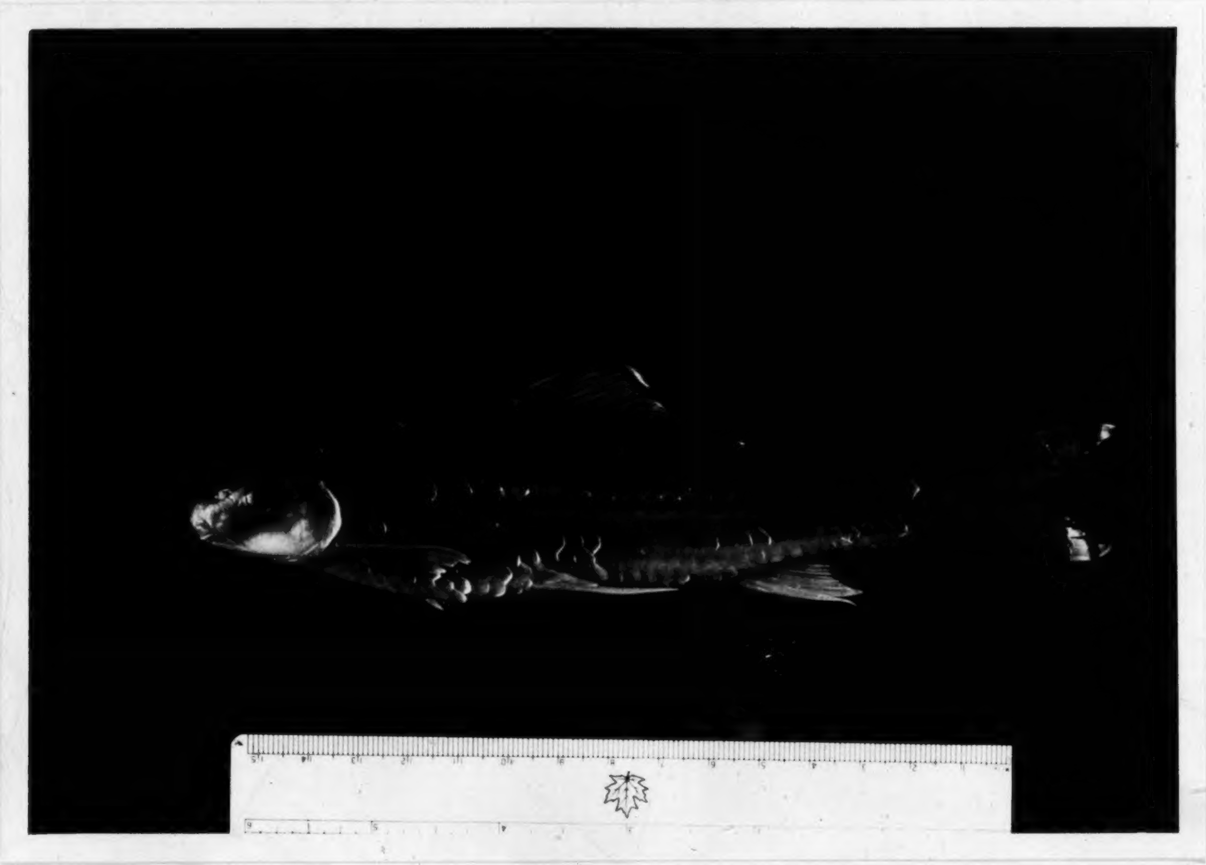

Fig. 15 Osteochilus sarawakensis new species Holotype

Osteochilus harrisoni Fowler

Osteochilus harrisoni Fowler, 1905: p.481; original description; type locality: Baram River, Boneo; Holotype ANSP 114892: 166.7 mm.; standard length; paratype, same catalogue number: 152.6 mm. standard length.

Osteochilus harrisoni Weber & de Beaufort, 1916: vol.3, p.139; description (after Fowler, 1905)

Nomenclature

Fowler described *Osteochilus harrisoni* in 1905 from two specimens collected by Mr. Alfred C. Harrison Jr. in Baram River, Borneo. Fowler noted that this species was close to *O. kahajanensis* without actually having seen specimens of the latter species. Weber & de Beaufort (1916) did not see Fowler's type specimens. They stated that they were not sure about the validity of this species as Fowler did not say anything about the presence or absence of pores on the snout. No additional specimens have been collected since 1905. My examination of the two known specimens shows that these two species are not closely related. From studying of the original description of *O. vittatus* (Cuv. & Val.), it seems probable that it is closely related to *O. harrisoni*. Unfortunately the type specimen of *O. vittatus* is in very bad shape and the coloration is gone (see also nomenclature discussion of *O. microcephalus* and *O. vittatus*, page 28 and 185).

Diagnosis

D. IV,15-17; l.l. 31-33; c.f. 11/2/13; c.p. 16

Osteochilus harrisoni has a long dorsal fin (15-17 branched rays). About ten longitudinal stripes along the body. Snout without tubercle or pores. Mouth subinferior; ventral surface of upper lip with long undivided costae. Gill rakers on the first gill arch 36 (counted on paratype)

Osteochilus harrisoni is closely related to *O. sarawakensis* but *O. sarawakensis* has a shorter dorsal fin and fewer rays (IV, 11–13) and about five to eight rows consisting of spots instead of continuous stripes as in *O. harrisoni*. *O. harrisoni* is also related to *O. pentalineatus*, but the latter species has a shallower body, a shorter dorsal fin (IV, 10), and only five stripes on the body.

Description

Body oblong and compressed, depth 358–374 (in thousanths of standard length). Head 231–242; eye 53–56. Snout 81–83; entire without tubercles or pores; snout longer than eye diameter, shorter than interorbital space, and about equal to postorbital length in adult fish. Interorbital space slightly convex, 131–132. Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed long undivided costae. Predorsal length 423, origin of dorsal fin opposite 9th–10th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin of a normal height, its fourth simple ray much shorter than the base of dorsal fin 327–329; branched dorsal rays 15–17. Insertion of dorsal fin opposite 21st–23rd scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from −1 to 2. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th scale of lateral line. Prepelvic length 461, pelvic fin insertion opposite 11th scale of lateral line. Preanal length 773; anal fin concave, third simple ray rather weak; anal fin origin opposite 22nd–23rd scale of lateral line. Caudal fin deeply forked its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 126–147; least depth of caudal peduncle 146–147, greater than half of the head length, and surrounded by 16 scale rows. Scales with nearly parallel radii, predorsal scales 10; circumferential scale 11/2/13 (5.5/1/4.5 in transverse series to the base of pelvic fin). Lateral line scale 31–33, with two additional pored scales on caudal base, lateral line somewhat straight but slightly curved upward anteriorly, lateral line scales with simple tubes. Gill rakers on the first gill arch 36 (measured from paratype).

Preserved specimens are dark brownish green on upper two fifth of the body, the dorsal part of head and back darker. Body marked with a longitudinal stripe on each scale row, (about 10 stripes along side) of the body; the stripes are equally distinct. Dorsal and caudal fin darker with melanophores other fins hyaline. Coloration of fresh specimens unknown.

Distribution

Only two specimens known from Baram River, Sarawak, 4th Division, northwestern Borneo.

Habitat

Unknown

Material Examined (2 specimens 166.7 mm, 152.6 mm, standard length)

ANSP 114892: (Holotype and Paratype) Baram River, Borneo.

Table 16 Proportional Measurements of *O. harrisoni* (measurements expressed as thousandths of standard leng[illegible]

Characters	Holotype	Paratype
Standard length (mm)	166.7	152.6
Depth	358	374
Head	242	231
Eye	56	53
Snout	83	81
Interorbital	132	131
Base of dorsal fin	327	329
Fourth simple dorsal ray	238	212
Predorsal length	423	
Prepelvic length	461	
Preanal length	773	
Anal fin height	208	224
Pelvic fin length	211	216
Pectoral fin length	215	221
Depth of caudal peduncle	146	147
Length of caudal penduncle	147	126
Lateral line scales	33	31
Predorsal scales	10	10
Circumferential scales		
Transverse scales		
Circumpeduncular scales	16	16
Dorsal branched rays	15	17

Pectoral rays	15	15
Gill rakers		36
Maxillary barbels	8.2	7.5
Rostral barbels	3.1	1.6

Osteochilus pentalineatus Kottelat

The following information is modified from that kindly provided by Mr. Maurice Kottelat. The description of this species is currently in press (Fishes from the Mentaya Drainage, Revue Suisse de Zoology, 1981).

Holotype: the only known specimen; Museum d' Histoire Naturelle, Geneva, Switzerland (cat. no. unknown) 56.4 mm. standard length, type locality; Mentaya Drainage, Southern Borneo.

Diagnosis

D. IV,10; l.l. 30, c.f. 9/2/13, c.p. 12

Osteochilus pentalineatus has five longitudinal stripes on the body, one on the lateral line, two above and two below. The scales are rather large, there being only 7/2/9 circumferential scales, and only 12 circumpeduncular scales.

O. pentalineatus shares some characters with *O. harrisoni* and *O. sarawakensis* but differs in having a shorter dorsal fin, fewer circumferential scales, and a lower number of stripes.

Description

Body oblong, slender, and compressed; depth 255 (in thousanths of standard length). Head 235; eye 75. Snout 82; without tubercles but numerous pores in the front. Snout longer than eye diameter interorbital space, about equal to the postorbital length in adult fish. Interorbital space slightly convex, 122. Mouth subinferior, two pairs of well developed barbels. Predorsal length 438; origin of dorsal fin opposite 9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin of normal height, the length of the fourth simple ray 205, and the base of dorsal fin 250; branched dorsal fin rays 10. The insertion of dorsal fin opposite 18th scale of lateral line, number of scales from posterior base of dorsal tin to vertical from anal fin origin three. Tip of pectoral fin not reaching the pelvic fin insertion, opposite 8th scale of lateral line. Prepelvic length 505; pelvic fin insertion opposite 11th scale of lateral line. Preanal length 800; anal fin concave, third simple ray rather weak; anal fin opposite 21st scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 130; caudal peduncle surrounded by 12 scale rows. Circumferential scales 9/2/13 (4.5/1/4.5 in transverse series to the base of the pelvic fin), lateral line scales 31, with two additional pored scales on caudal base. Lateral line somewhat straight, its scales with simple tube.

Preserved specimens are dusky on the upper two fifths of the body, the dorsal part of head and back darker. Ground color reddish brown, five blackish brown longitudinal stripes, one running along lateral line, two above and two below. Fins hyaline; extremity of median caudal rays dark. A row of dark spots on the membrane between the dorsal rays in about 1/3 of its height. These spots are more distinct posteriorly.

Distribution

Mentaya River, Southern Borneo.

Habitat

Unknown.

Material

Not seen, description based on Mr. M. Kottelat's original description and photograph of the Holotype.

Table 17 Proportional Measurements of *O. pentalineatus* (measurements expressed as thousandths of standard length)

Characters	Holotype
Standard length (mm)	56.4
Depth	255
Head	235
Eye	75
Snout	82
Interorbital	122
Base of dorsal fin	250
Fourth simple dorsal ray	205
Predorsal length	438
Prepelvic length	505
Preanal length	800
Anal fin height	165
Pelvic fin length	180
Pectoral fin length	170
Depth of caudal peduncle	
Length of caudal penduncle	130
Lateral line scales	31
Predorsal scales	
Circumferential scales	
Transverse scales	
Circumpeduncular scales	12
Dorsal branched rays	10

Pectoral rays	14
Gill rakers	
Maxillary barbels	
Rostral barbels	

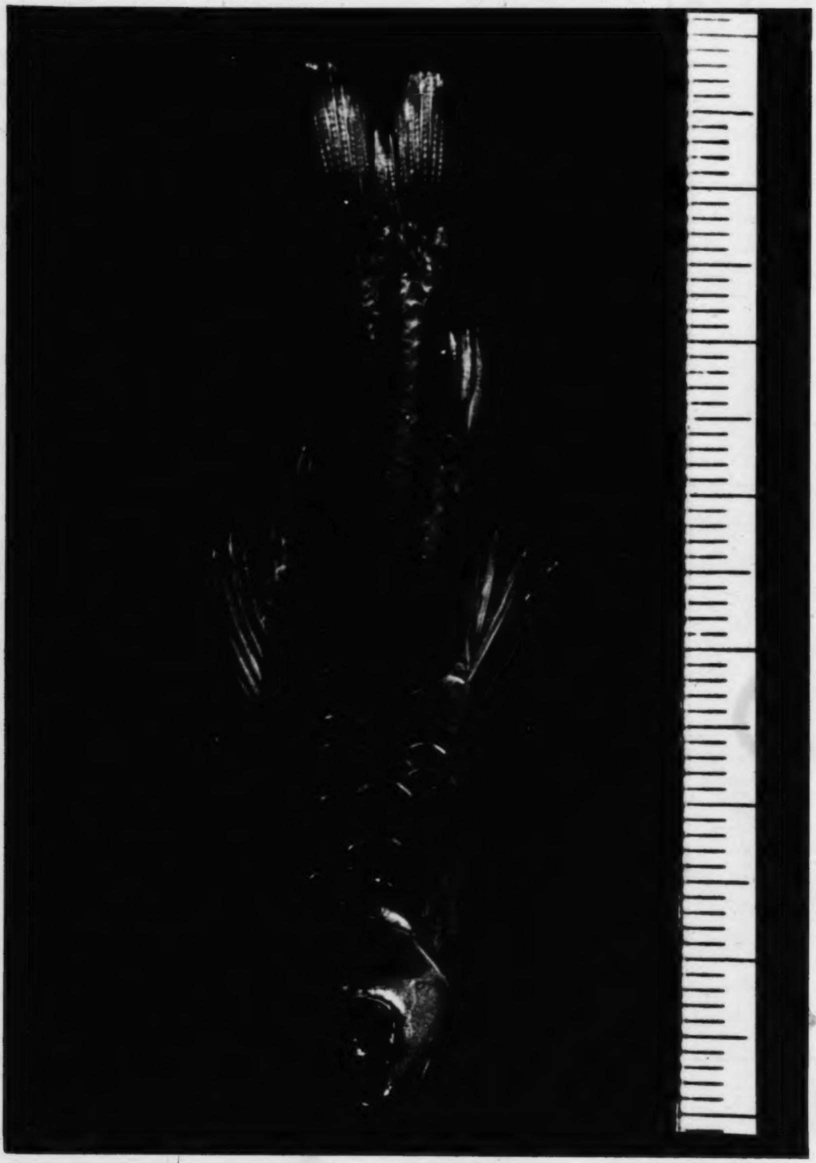

Fig. 16 Osteochilus pentalineatus Kottelat Holotype

Osteochilus hasselti (Valenciennes)

Rohita hasselti Valenciennes in Cuvier and Valenciennes, 1842: Vol.16, p.209; original description; type locality: Java; syntypes: 5 specimens (3 dry, 2alc.) RMNH 2188, dry (216.8 mm, S.L.); RMNH 2177, dry (141.1 mm S.L.); RMNH 2120, dry (104.4 mm S.L.); RMNH 2588, in alc. (2 spec., 136.1, 109.7 mm, S.L.)

Rohita rostellatus Cuv. and Val., 1842: vol.16, p 250; original description; type locality: Rangoon, Burma; holotype MHNP 85-177-31-1, 75.1 mm in standard length.

Rohita (Rohita) kuhli Bleeker, 1860: vol.2, p.177; original description; type locality: Palembang, Sumatra; holotype BMNH 1866.5.2.171, 160 mm total length (given by Bleeker) 116.7 mm standard length (my measurement).

Rohita (Rohita) hasselti Bleeker, 1863: vol.3, p.65; description; locality: Java, Sumatra, Borneo (78 specimens); with color plate.

Osteochilus hasselti Gunther, 1868: vol.7, p.41; description; locality: Java, Sumatra, Borneo.

Osteochilus kuhlii Gunther, 1868: vol.7, p.43: description; Bleeker's specimen.

Osteochilus neilli Day, 1870: p.99; original description; type locality: Sittang River, Burma; syntype (2 specimens) ZSI 699, 60.9 mm and 52.9 mm standard length (my measurement)

Osteochilus neilli Day, 1876: p. 545, plt 80, fig.2; description; locality Sittang and Billing in Burma.

Osteochilus neilli Day, 1889: vol.1,p.274, fig. 94; description; locality: Rangoon, Burma.

Osteochilus hasselti Weber & de Beaufort, 1916: vol.3, p.135; description; locality Sumatra, Java, Borneo, Malacca, and Siam.

Osteochilus hasselti Tirant, 1929: p.151; description; locality: Cochinechine and Cambodia.

Osteochilus duostigma Fowler, 1937: p 182, fig. 120, 121; original description; type locality Kemarat, northeastern Thailand; holotype ANSP 68069, 115 mm total length (given by Fowler), 85.7 mm standard length (my measurement)

Osteochilus hasselti Smith, 1945: p.214; description; locality: various parts of Thailand, Mekong basin (Laos & Cambodia).

Osteochilus hasselti tweediei Menon, 1954: p.12, fig 3; original description; type locality Kuala Tahan, Pahang, Malaysia; holotype ZSI F324/2, 118.9 mm standadrd length (my measurement).

Nomenclature

Osteochilus hasselti is one of the commonest species of the genus, it has been found almost throughout the range of the genus except in N. Vietnam, China, and eastern Borneo. This species demonstrates considerable geographical variation in body proportion, color pattern, and length of dorsal fin, and for this reason, many nominal forms of it have been described. The majority of *O. hasselti* specimens have a rather deep body, long dorsal fin (15-17 branched dorsal rays), with about 6-9 rows of spots or stripes on the posterior two-thirds of the body. Some specimens have a black blotch on the scales above the middle part of the pectoral fin; this form represents the nominal form of *O. neilli* Day (Burma) and *O. duostigma* Fowler (Thailand). This character is only seen in young specimens. Some specimens have a rather slender body and short dorsal fin (12-13 branched dorsal rays) which are usually found in eastern Malaysia, the islands between Sumatra and Borneo, Sumatra, and Java in possible response to the running water habitat; this form is a norminal form of *O. hasselti tweediei*. This subspecies, described by Menon (1954) was based on specimens from Pahang, eastern Malaysia. The type specimen of *O. hasselti* also represents this form (with 13 branched dorsal rays), therefore, I do not recognize Menon's subspecies. The syntypes of *O. hasselti* (Cuv. & Val.) are dry mounted varnished specimens that have been ignored for a long time because Bleeker's (1963) Atlas and figure have been so useful. *O. hasselti* of Bleeker represents the common form which many ichthyologists accept as typical. This form has faint rows of spots which sometimes disappear after death or preservation in alcohol. It represents the nominal form of *Osteochilus kuhli* Bleeker.

Diagnosis

D. IV,12–17; l.l. 30–33; c.f. 11/2/13; c.p. 16

The number of branched dorsal rays varies widely in *Osteochilus hasselti*. There are 15–17 rays in specimens of most populations (and only this) on the mainland, but there are 12–14 rays in some populations in the archipelago area. There are 6–9 rows of spots or stripes on the posterior two-thirds of the body; some young specimens have a black blotch on the scales above the pectoral fin.

O. hasselti shares some characters with *O. sarawakensis* such as the rows of spots or stripes on the body; However, *O. sarawakensis* has an inferior mouth with long undivided costae on the ventral part of the upper lip, while *O. hasselti* has short divided costae on the lip. *O. sarawakensis* also has a short dorsal fin of 11–13 branched rays.

O. hasselti is closely related to *O. kappeni*. The differences that separate them are: circumferential scales 13/2/15; body deeper and more compressed; rows of spots on the body are not distinct in *O. kappeni*

Description

Body oblong and slightly compressed; depth 327–410 (mean=368) (in thousandth of standard length), head 219–258 (mean=254); eye 42–70 (mean=57), large fish with relatively small eye. Snout 67–91 (mean=79), entire, without tubercles or pores; snout longer than eye diameter in adult fish, shorter than interorbital space, shorter than postorbital part of the head. Interorbital space slightly convex, 114–143 (mean=122). Mouth ascending, two pairs of well developed barbels; maxillary barbels longer than or about equal to eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed short, divided, costae. Predorsal length 420–440 (mean=433), origin of dorsal fin opposite 8th to 10th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually with normal height, length of fourth simple ray 227-294 (mean=268), base of dorsal fin 324-403 (mean=372) and branched dorsal rays 15-18 (specimens from Java, and Biliton Island may have 12-14 rays). The insertion of the dorsal fin opposite 22nd-24th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from -2 to 0. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 8th-10th scale of lateral line. Prepelvic length 421-580 (mean=516); pelvic fin insertion opposite 11th-12th scale of lateral line. Preanal length 761-903 (mean=792); anal fin concave, third simple ray rather weak; anal fin origin opposite 22nd-24th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Least depth of caudal peduncle 133-156 (mean=142), usually greater than its length, and more than half of head length; length of caudal peduncle 101-143 (mean=113). Caudal peduncle surrounded by 16 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales usually 9-11; circumferential scales 11/2/13 (5.5/1/4.5 intransverse series to the base of pelvic fin); lateral line scales 30-33 with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 27-35.

Preserved specimens are dusky on the upper two-fifths of the side; the dorsal part of head and back are darker; six to nine longitudinal rows of spots or stripes on posterior two-thirds of the body. A large round black spot is present on the caudal peduncle. Some young specimens also have a dark blotch formed by dark bars on the fifth scale of the lateral line, and on the one above and the one below (above the middle part of the pectoral fin). Dorsal and caudal fins with melanin pigment in the membranes, other fins plain. Coloration of fresh specimens olive-brown with orange spots between the rows of black spots; all fins are pinkish.

Distribution

O. hasselti has a wide distribution from Burma eastward to as far as the Mekong Basin and its tributaries, southward to Malay Peninsula and the Islands of the archipelago west of Wallace's line.

Habitat

Lakes and large rivers with still or slow moving water at the low elevations with turbid warer, It can occur in running water but never in swift water.

Material examined (530 specimens 54.8–224.0 mm standard length)

Syntypes: RMNH 2117, 2118, 2120 (3 spec., dry, mounted), Java
RMNH 2588 (2 spec., alc.) (said to be syntypes)
Java

Other specimens:
ZSI 669 (2 spec., syntypes of *O. neilli*) Sittang,
Burma
MHNP 85-177-31-1 (1 spec., type of *O. rostellatus*)
Rangoon, Burma.
ANSP 68096 (1 spec., type of *O. duostigma*)
Kemarat, Thailand
ZSI 324/2 (1 spec., type of *O. hasselti tweediei*)
Kuala Tahan, Pahang

Borneo : BMNH 1904.1.20.2 (1 spec.) no spacific locality
BMNH 1898.11.14.5 (1 spec.) Sarawak, Baram River
FMNH 68543 (2 spec.) Sungai Subis, Sarawak 4th Div.
FMNH 62991 (21 spec.) R. Niah, Sarawak 4th Div.
FMNH 68854 (1 spec.) Sungai Tangap, Sarawak 4th Div.
FMNH 68853 (1 spec.) Sungai Tangap, Sarawak 4th Div.
FMNH 62985 (1 spec.) R. Niah, Sarawak 4th Div.
FMNH 62986 (1 spec.) R. Niah, Sarawak 4th Div.

FMNH 68707 (1 spec.) Sungai Subis, Sarawak 4th Div.

FMNH 68544 (2 spec.) Lower Niah, Sarawak 4th Div.

FMNH 68850 (1 spec.) Kampon Tangap, Sarawak 4th Div.

FMNH 68852 (2 spec.) Niah, Sarawak 4th div.

KCTR 76-8 (9 spec.) Sungai Keniyatan, about 65 km N.E. of Pontianak (tributary of Kapuas)

Burma: RMNH 8622 (1 spec.) no spacific locality

ZSI 667 (1 spec.) Sittang River

Bali: BMNH 1974.10.10.886 (1 spec.) Darau Tamblingan

BMNH 1974.10.10.888 (1 spec.) Darau Tamblingan

BMNH 1974.10.10.884-885 (2 spec.) Darau Buyam

BMNH 1974.10.10.880-883 (3 spec.) Darau Batan

Indochina: MHNP 85-177-13-8 (3 spec.) Cochinchina

UMMZ 181131 (4 spec.) Prek Tock, Prey Veng Prov., Cambodia

UMMZ 181187 (1 spec.) Fish pond at Bamnak, Pursat Prov., Cambodia

UMMZ 181153 (1 spec.) Prek Angkor 15 km west of Phnom Penh, Cambodia

UMMZ 182250 (1 spec.) Great Lake at Kampong Laung, Cambodia

Java: BMNH 1974.10.10.875-879 (5 spec.) Telaga Patengan, near Bandung

MHNP 85-177-13-10 (2 spec.) Batavia

UMMZ 155735 (3 spec.) Fish pond near Trogong

UMMZ 155577 (3 spec.) no specific locality

UMMZ 155732 (2 spec.) fish pond near Singaparna

UMMZ 155737 (1 spec.) Vic Bandveng (market)

UMMZ 155731 (1 spec.) Lake Tjiboeroej

UMMZ 155733 (1 spec.) Tjitandej Godebak

Malaysia (continental), and Singapore:

BMNH 1882.5.19.22-24 (3 spec.) Telom River, Pahang

BMNH 1931.7.20.34 (1 spec.) Tasek Bera, Pahang

AMNH 13831 (1 spec.) Sungai Lampan, Perak

FMNH 42429 (2 spec.) Lake Chin Chin, Malacca

NMNH 101258 (3 spec.) Lake Chin Chin, Malacca

NMS 629 (2 spec.) Lake Chin Chin, Malacca

NMS 627 (2 spec.) Kakai Bukit, Peris

NMS 630 (2 spec.) Kuala Tahan, Pahang

NMS 634 (3 spec.) Lake Chini, Pahang

NMS (uncatalogued, 3 spec.) Singapore

MHNP 85-177-13-11 (3 spec.) Malacca

Sumatra: AMNH 9502 (1 spec.) Padangsche, Bovenlanden

AMNH 9501 (1 spec.) Kalung (Tilatang), Padangsche, Bovenlanden

AMNH 9297 (1 spec.) Djambi, Batang Hari River

ANSP 17307 (68 spec.) Buta Songkar, Padangsche, Bovenlanden

ANSP 32377 (1 spec.) Padang

ANSP 27305-6 (2 spec.) Batu Songkar, Padangsche, Bovenlanden

RMNH 13729 (1 spec.) lat. 4 degree N., long. 98-49 degree E.

RMNH 26911 (1 spec.) Sockadana

RMNH 17611 (7 spec.) River Poeloeweh

UMMZ 155582 (1 spec.) Moesi River, Maeara Klingi

ZMA 116.087 (6 spec.) Padang Benedenloop

ZMA 116.084 (1 spec.) Patang Hari River, Djambi

ZMA 116.102 (2 spec.) River near Solok

ZMA (uncatalogued, 3 spec.) Fort de Kock

ZMA (uncatalogued, 1 spec.) Talack

Biliton Island: ZMA 116.092 (4 spec.)

Thailand: AMNH 14583 (1 spec.) Chanthaburi River

ANSP 58060 (1 spec.) Chanthaboon

ANSP 57506 (2 spec.) Chanthaboon (with 11 spec.of *O. lini*

ANSP 87862 (10 spec.) Huey Yang

ANSP 57508 (1 spec.) Chiengmai

ANSP 57507 (1 spec.) Chiengmai

ANSP 89404 (18 spec.) Huey Yang

ANSP 76817 (4 spec.) Krabi

ANSP 60329 (1 spec.) Trad

ANSP 60843-44 , 60941-42 (4 spec.) Bangkaok

ANSP 60325-6 (2 spec.) Ban Thung Luang (near Hua Hin)

BMNH 1934.12.18.14 (1 spec.) Hang Kra Ben, Chao Phya River

NMNH 108039 (2 spec.) Pattani River

NMNH 108052 (2 spec.) Talesap, Songkhla

NMNH 108051 (1 spec.) Chanthaboon River

NMNH 103260 (1 spec.) Bukit, Pattani

NMNH 108053 (1 spec.) Tale Noi, Songkhla

NMNH 108040 (1 spec.) Talesap, Songkhla

NMNH 108030 (1 spec.) Meklong at Ban Pong

RMNH 16462 (1 spec.) Pattalung

UMMZ 201055 (4 spec.) Chao Phya River

UMMZ 201066 (3 spec.) Huay Kwang, Ubol

UMMZ 201056 (1 spec.) Creek at Ban Tha Mai, Ubol

UMMZ 201058 (1 spec.) Lam Pao Reservoir, Kalasin

UMMZ 201059 (4 spec.) Lam Pao Reservoir, Kalasin

UMMZ 201065 (1 spec.) Lam Pao Reservoir, Kalasin

UMMZ 201060 (1 spec.) Lam Pao Reservoir (S.W.end)

UMMZ 201061 (1 spec.) Huay Thom-Loe at Ban Bung

UMMZ 201063 (2 spec.) Lam Pao Reservoir, Kalasin

UMMZ 201064 (2 spec.) Mekong River, at Ban Tha Sadet, Nong Khai

UMMZ 201057 (1 spec.) Mun River at Ban Dan, Ubol

UMMZ 195372 (4 spec.) Chao Phya River at Maharaj District

UMMZ 195791 (1 spec.) Huay Ban Yang Reservoir, North of Korat

UMMZ 195757 (10 spec.) Reservoir of Mahasarakam

UMMZ 195679 (12 spec.) Market at Ubol

NIFI (uncatalogued, 10 spec.) Chao Phya River at Ayuthya

NIFI (uncatalogued, 56 spec.) Ubolratana Reservoir

NIFI (uncatalogued, 15 spec.) Huay Luang, Udorn

NIFI (uncatalogued, 21 spec.) Mekong River at Nong Khai

NIFI (uncatalogued, 16 spec.) Lamdome Noi, Ubol

NIFI (uncatalogued, 38 spec.) Nongharn, Sakol Nakorn

NIFI (uncatalogued, 24 spec.) Bung Borapet, Nakorn Sawan

NIFI (uncatalogued, 4 spec.) Meping at Cheingmai

NIFI (uncatalogued, 14 spec.) Meklong River at Karnchanaburi

NIFI (uncatalogued, 4 spec.) Surathani

NIFI (uncatalogued, 20 spec.) Chanthaburi River

NIFI (uncatalogued, 9 spec.) Petchaburi

NIFI (uncatalogued, 3 spec.) Chumporn

Table 18 Proportional measurements of *O. hasselti* (measurements expressed as thousandths of standard length)

Characters	type	other specimens	
		mean	S.D.(n=525)
Depth	304	369	30.8
Head	195	254	33.4
Eye	49	57	10.3
Snout	70	79	8.5
Interorbital space	108	123	8.4
Base of dorsal fin	319	373	28.6
Fourth simple dorsal ray		368	22.4
Predorsal length		433	21.7
Prepelvic length		516	28.8
Preanal length		792	43.9
Third simple anal ray		232	17.6
Pectoral fin length		207	31.1
Pelvic fin length		222	17.9
Depth of caudal peduncle	114	142	7.6
Length of caudal peduncle	125	113	12.5
Lateral line scales	32	32.5	1.5
Predorsal scales	11	10.1	0.7
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5/1/4.5	
Circumpeduncular scales	16	16	

			156
Dorsal branched rays	14	15.6	1.9
Pectoral rays	14	15.4	0.5
Gill rakers		29.4	1.7
Maxillary barbel		66	12.0
Rostral barbel		27	4.5

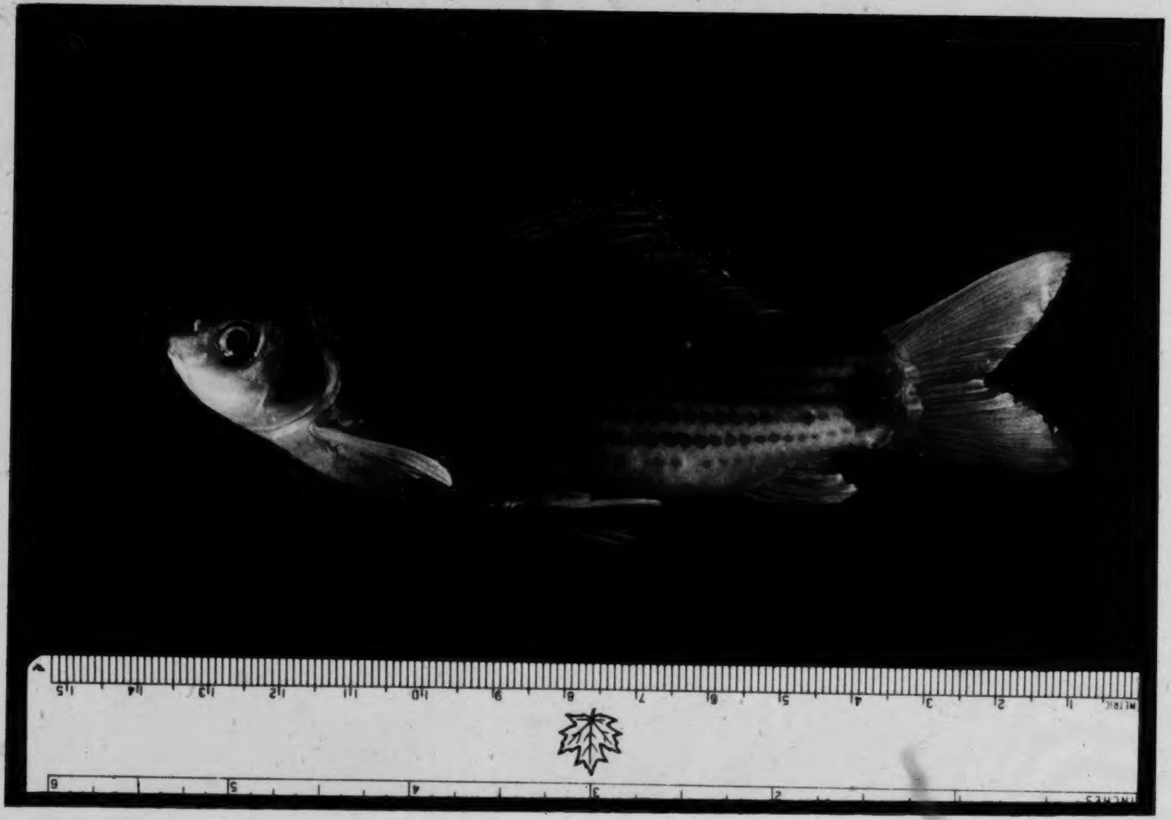
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Fig. 17 *Osteochilus hasselti* (Cuv. & Val.) NIFI (uncatalogued) Mekong River

Osteochilus *kappeni* (Bleeker)

Rohita kappenii Bleeker, 1857: p.19; Original description; Type locality, River Kapuas at Pontianak; Holotype BMNH 1866.5.2.174 ?; 120 mm total length (given by Bleeker), 86.0 mm standard length (my measurement).

Rohita (Rohita) kappenii Bleeker, 1860: vol.2, p.167; redescription (same specimen), with color plate.

Osteochilus kappenii Gunther, 1868: vol.7, p.42; redescription (from Bleeker's specimen).

Osteochilus kappenii Weber & de Beaufort, 1916: vol.3, p.137; description; locality Sumatra (Djambi). I have not seen the specimen.

Osteochilus brevicauda Weber & de Beaufort, 1916: vol.3: p.138; original description; type locality: Kapuas River at Putus Sibua, Putus Genting; Borneo; syntype ZMA 100.167 (1 spec, 175.0 mm S.L.), ZMA 112.675 (6 spec, 46.8-67.2 mm S.L.).

Nomenclature

Osteochilus kappenii was described by Bleeker in 1857, and redescribed from the same specimen in 1860 and 1863. There was a slight difference in the description of 1857 from that given in 1863 as follows: 32-34 vs 33-34 lateral line scales 12 vs 14.5(15) scales in transverse series, and 6 vs 6.5(7) scales above lateral line to origin of dorsal fin. Gunther (1868) claimed that the type specimen of this species was BMNH 1866.5.2.174. In my examination of this specimen I counted 5.5 scales from above the lateral line to the origin of the dorsal fin, and 30+2 scales along the lateral line (same on both sides of the body). I am not sure that this specimen is really the type that Bleeker used or not; in addition, the difference within Bleeker's papers is unexplainable.

In 1916, Weber and de Beaufort described *O. brevicauda* on the basis of minor differences. He used two characters to separate these two species as follows the number of scales below the lateral line to the mid-line of the abdomen (6.5 in

O. kappenii and 7.5 in *O. brevicauda*) and the shape of the black blotch on the caudal peduncle. From my study of other additional specimens, I find that these two characters vary within the species. Since I am not certain about the type specimen, I have based my description of this species on Bleeker's (1863) illustration which has 32+2 lateral line scales, 6.5/1/5.5 transverse scales to the base of pelvic fin, and 16 branched dorsal rays. These characters agree with the *O. brevicauda* of Weber and de Beaufort.

Diagnosis

D. IV,15-17; l.l 31-33; c.f. 13/2/15; c.p.16

O. kappeni has a deep body with 13/2/15 circumferential scales, 6.5/1/5.5 transverse scales to the base of pelvic fin; and a large round black blotch on the caudal peduncle. In young specimens there is an indication of an incomplete brown vertical band above and below the lateral line, and above the mid-portion of the pectoral fin.

O. kappeni is related to *O. hasselti* and it is quite difficult to distinguish between these two species. *O. hasselti* has larger scales, a more slender body, and 11/2/13 circumferential scales. There are rows of spots on the body in both species but they are very distinct in *O. hasselti*, while in *O. kappeni* the rows of spots are small and faint and usually disappear in adult specimens.

Description

Body oblong, deep and compressed, depth 351-446 (mean=385) (in thousanths of standard length). Head 242-300 (mean=268), eye 51-94 (mean =78), large fish with a relatively small eye. Snout 72-103 (mean=87) entire, without tubercles or pore; about equal or a little longer than eye diameter, shorter than interorbital space, usually shorter than the postorbital part of the head. Interorbital space slightly convex, 115-144 (mean=127). Mouth subinferior, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels usually shorter than the maxillary ones. Ventral surface of upper lip consists of well developed short costae, most of which are divided into more than two portions. Predorsal length 424-459 (mean=439); origin of dorsal fin opposite 7th or 9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin long and normal in height, its fourth simple ray shorter than the base of the dorsal fin, the length of fourth simple ray 247-311 (mean=289), and the base of dorsal fin 334-406 (mean=377); branched dorsal rays 15-17. Insertion of the dorsal fin opposite 22nd - 24th scale of lateral line, number of scales from posterior base of dorsal fin to vertical from anal fin origin varies from -2 to 0. Tip of pectoral fin not reaching the pelvic fin insertion, usually opposite 9th-12th scale of lateral line. Prepelvic length 523-559 (mean=539); pelvic fin insertion opposite 11th-12th scale of lateral line. Preanal length 768-831 (mean=796); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st-24th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 94-153 (mean=143); least depth of caudal peduncle 130-151 (mean=143), and surrounded by 16 scale rows. Scales with few radii, parallel centrally and radiating laterally; predorsal scales 9-11; circumferential scales 13/2/15 (rarely 11-12/2/15), scales in transverse series to the base of pelvic fin 6.5/1/5.5 (rarely 5.5/1/5.5). Lateral line scales 31-33, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 26-34.

Preserved specimens are dusky on the upper two-fifths of the side, the dorsal part of head and back are darker. There is a large round black blotch on the caudal peduncle and spots in rows which are irregular, usually faint, and disappear in adult specime Young specimens also have a dark incomplete bar at the two or three scales above and below the lateral line and opposite the mid-portion of the pectoral fin. Dorsal and caudal fin with melanin pigment in its membrane other fins clear. Coloration of fresh specimen unknown.

Distribution

All specimens studied are from the Kapuas River, Borneo. Weber and de Beaufort reported this species from Djambi Sumatra (not seen; it is possible that this species occurs there). Fowler (1905) reported *O. kappeni* from the Baram River in Sarawak (not seen); from his description it is more probably *O. kahajanensis*.

Habitat

Small or large rivers with weak current and turbid waters seem to prefered.

Material Examined (17 specimens 46.8 mm −175.0 mm standard length)

Holotype BMNH 1866.5.2.174 (?) Kapuas River, Pontianak, Borneo

Syntypes of *O. brevicauda* (7 specimens)

ZMA 100.167 (1 spec.):Kapuas River at Putus Sibau, Borneo.

ZMA 112.675 (6 spec.):Kapuas River at Putus Genting, Borneo.

Other specimens:

MHNP 85-177-17-1 (2):Borneo

AMNH 9273 (1):Borneo, Poetus Genting (presumably from ZMA 112.675).

KCTR 76-37 (2):small forested stream where it flows into Sungai Mandai 2-3 km upstream from its Kapuas mainstream, 17 km WSW of Putussibau, (current weak, water turbid).

KCTR 76-28 (3):small forested streams flowing into Sungai Pinoh near village of Ribang-Rabing ; about 55 km SSE of Nangapinoh and 2 km NE of Katabahru.

KCTR 76-43 (1):small oxbow lake completely cut off from Kapuas mainstream opposite Empangau, 124 km NE of Sintang.

Table 19 Proportional Measurements of *O. kappeni* (measurements expressed as thousandths of standard length)

Characters	type		other specimens	
	BMNH	illust.	mean	S.D.(n=16)
Standard length (mm)	86.0	89.4		
Depth	384	380	385	23.9
Head	242	263	268	19.2
Eye	71	64	78	13.0
Snout	84	103	87	7.0
Interorbital	122		127	7.3
Base of dorsal fin	377	384	377	23.9
Fourth simple dorsal ray	305	287	289	20.5
Predorsal length		403	439	13.0
Prepelvic length		496	539	14.0
Preanal length		752	796	22.0
Anal fin height	238	210	252	12.1
Pelvic fin length	234	225	237	15.8
Pectoral fin length	231	227	236	8.6
Depth of caudal peduncle	151	150	143	6.2
Length of caudal penduncle	143	144	117	12.9
Lateral line scales	30	32	32	0.7
Predorsal scales	9	11	10.2	0.8
Circumferential scales				
Transverse scales				
Circumpeduncular scales	16	16	16	

Dorsal branched rays	15	16	16.2	0.7
Pectoral rays	15		15.2	0.6
Gill rakers	39		29.2	3.8
Maxillary barbels	60		89	14.7
Rostral barbels	28		39	7.9

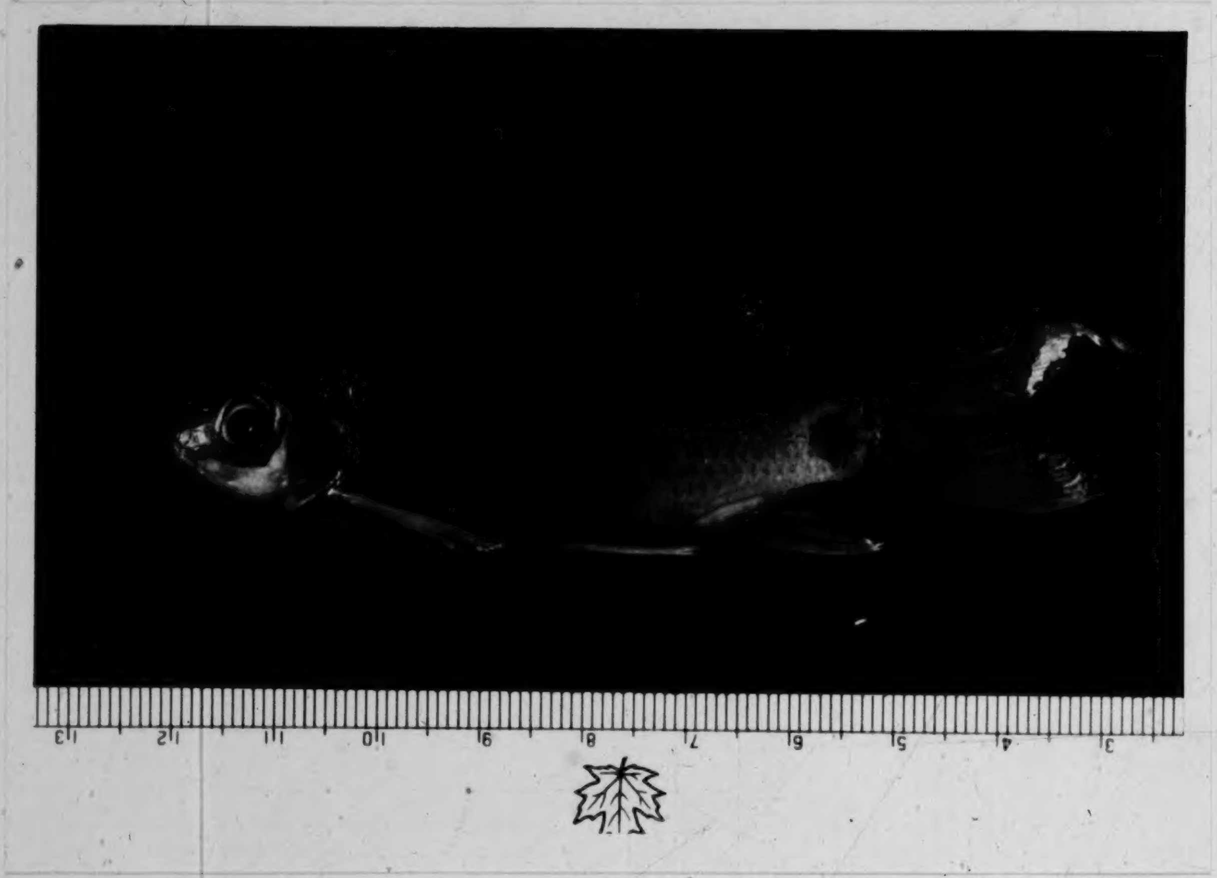

Fig. 18 Osteochilus kappeni (Bleeker) KCTR 76-28

Osteochilus lini Fowler

Osteochilus lini Fowler, 1935: p118, figs. 54,55; original description; type locality: Khao Nam Poo, northern part of central Thailand; holotype ANSP 60812, 84mm total length (given by Fowler), 63.2 mm standard length (my measurement); paratype (29 spec.) 65-83 mm total length (given by Fowler), 51.2-57.1 mm standard length (my measurement).

Osteochilus lini Smith, 1945: p216; referring to Fowler's description.

Osteochilus duostigma Smith, 1945: p215 (in part); locality: Khao Sabab, south estern Thailand.

Nomenclature

Osteochilus lini was described from 30 specimens from Khao Nam Poo, Thailand in 1935. Smith (1945) did not see Fowler's materials and misidentified *O. lini* as *O. duostigma* (=*O. hassilti*) as the two forms are similar. In the original description, Fowler did not indicate whether or not there are pores or tubercles on the snout , but in his illustration of *O. lini* there are several spots drown on the snout. On the basis of Fowler's picture Smith believed that *O. lini* has pores on the snout and he identified his specimens of *O. lini* as *O. duostigma*. I have examined the type specimens of *O. lini* and all of them have entire snouts without pores or tubercles.

Diagnosis

D. IV,12-13 (rarely 14-15); l.l. 32-34; c.f. 11/2/13: c.p. 16

O. lini has a black blotch on the side above the pectoral fin, formed by two or three black bars on the fifth scale of the lateral line and the scale immediately above and below it. The under surface of the upper lip consists of short divided costae.

O. lini shares some characters with *O. hasselti* such as the structure of the mouth and general body shape, but *O. hasselti* has rows of spots on the body while

O. lini has only one black blotch on the side. *O. hasselti* also has a longer dorsal fin (15-17 branched dorsal rays on the mainland)

Description

Body oblong, deep, and compressed; depth 330-370 (mean=352) (in thousandths of standard length). Head 198-254 (mean=225), eye 43-62 (mean=54), large fish with relatively small eye. Snout 69-94 (mean=81); entire, without tubercles or pores; about equal to or a little longer than eye diameter, shorter than interorbital space, usually shorter than the postorbital part of the head. Interorbital space slightly convex, 107-123 (mean=113). Mouth subinferior, two pairs of well developed barbels; maxillary barbels about equal to or longer than eye diameter, rostral barbels usually shorter than the maxillary ones. Ventral surface of upper lip consists of well developed short, divided costae, most of which are divided into two or more portions. Predorsal length 380-445 (mean=415); origin of dorsal fin opposite 7th-9th scale of lateral line before mid point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin moderately long with normal height, its fourth simple ray 213-246 (mean=232) shorter than the base of dorsal fin 274-329 (mean=305) ; branched dorsal rays 12-14 (rarely 15). Posterior base of dorsal fin opposite 20th-21st scale of lateral line, number of scales from the posterior base of dorsal fin to vertical from anal fin origin varies from one to three. Tip of pectoral not reaching the pelvic fin insertion, usually opposite 7th-9th scale of lateral line. Prepelvic length 479-529 (mean=497); pelvic fin insertion opposite 10th - 12th (usually 11th) scale of lateral line. Preanal length 728-772 (mean=753); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st-23rd scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 112-139 (mean=124); least depth of caudal peduncle 131-147 (mean=140); surrounded by 16 scale rows. Scales with few radii parallel medially and radiating laterally; predorsal scales 9-11; circumferential scales 11/2/13 (transverse scales to the base of pelvic fin 5.5/1/4.5). Lateral line scales 31-34, with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 27-36. Preserved specimens are grayish brown, the back and the dorsal part of the head darker. Black blotch on the side formed by two or three black bars on the fifth scale of lateral line and one above and one below. This blotch is right above the middle part of the dorsal fin; other parts of the body uniformly gray. All fins are pale pink or whitish and hyaline.

Distribution

The distribution of *O. lini* is restricted to northern and eastern parts of central Thailand (Phetch-bun, Nakorn Nayok, Chanthaburi) and the lower Mekong Basin and its tributaries of northeastern Thailand.

Habitat

Found in both rivers, lakes, and mountain streams (at low elevation). The rapid or rocky parts of rivers are preferable, but it also does well in the ponds.

Materials examined (354 specimens 50.1-135.6 mm standard length).
holotype : ANSP 60812; Khao Nam Poo; Thailand
paratypes : ANSP 60813-41 (29 spec.); same data as holotype

Other specimens:

Thailand :

ANSP 57606 (11 spec)(3 specimens of this no. belong to *O. hasselti*, all specimens of this no. were identified as *O.hasselti*) Chanthaboon, southeastern Thailand.

ANSP 58060 (1 spec.) Chanthaboon, S.E. Thailand (this specimens of his number was identified as *O. hasselti*)

USNM 10857 (1 spec.) Pleiw water fall, Chanthaboon

USNM 108056 (2 spec.) Chanthaburi River, S.E.Thailand

USNM 108041 (1 spec.) Kao Bantad, Trad, S.E.Thailand

USNM 108042 (1 spec.) Trad River at Trad, S.E. Thailand. (all the USNM specimens were identified as *O. duostigma*)

UMMZ 201079 (2 spec.) Mekong River, back water at Tha Sadet, Nong Khai

UMMZ 201080 (7 spec.) wadeside ditch, near Ban Thang, Nakorn Phanom.

UMMZ 201078 (8 spec.) Mekong River, back water at Tha Sadet, Nong Khai.

UMMZ 201077 (3 spec.) Huay Thom-Loe, Ubol

NIFI uncatalogued (120 spec.) Ubolratana Reservoir, N.E. Thailand

NIFI uncatalogued (50 spec.) Ubolratana Reseroir N.E. Thailand

NIFI uncatalogued (3 spec.) Nakorn Nayok, central Thailand

NIFI uncatalogued (40 spec.) Nong Harn, Sakol Nakorn

NIFI uncatalogued (20 spec.) Huay Luang, Udorn

NIFI uncatalogued (15 spec.) Krating Water fall, Chanthaburi

NIFI uncatalogued (30 spec.) Ubolratana Reseroir

NIFI uncatalogued (8 spec.) Khon Kaen, N.E. Thailand

Cambodia:

UMMZ 181188 (4 spec.) fish pond at Bannak, Pursat Prov.

Table 20 Proportional measurements of *O. lini* (measurements expressed as thousandths of standard length)

Characters	type	other specimens	
		mean	S.D. (n=353)
Depth	328	352	12.1
Head	222	225	17.1
Eye	63	54	6.5
Snout	74	80	7.3
Interorbital space	114	113	4.4
Base of dorsal fin	278	305	15.8
Fourth simple dorsal ray	252	232	8.8
Predorsal length		415	17.0
Prepelvic length		497	12.0
Preanal length		753	10.0
Third simple anal ray	202	189	10.9
Pectoral fin length	210	200	9.9
Pelvic fin length	204	202	6.7
Depth of caudal peduncle	139	139	5.6
Length of caudal peduncle	160	124	9.0
Lateral line scales	33–34	32.9	0.5
Predorsal scales	10	10	0.5
Circumferential scales	11/2/13	11/2/13	
Transverse scales (to the base of pelvic fin)	5.5/1/4.5	5.5//4.5	
Circumpeduncular scales	16	16	

Dorsal branched rays	12	13	0.8
Pectoral rays	14	14	0.6
Gill rakers	29	30.3	3.0
Maxillary barbel	60	50	9.5
Rostral barbel	27	22	6.9

Fig. 19 Osteochilus lini Fowler NIFI (uncatalogued) Mun River

Osteochilus repang Popta

Osteochilus repang Popta, 1904: p.196; original description; type locality: River Bo, tributary of Mahakam River, Borneo; holotype RMNH 7579, 268 mm total length (given by Popta) 192.1 mm standard length (my measurement). 1906: p.101; description.

Osteochilus repang Weber and de Beaufort, 1916: vol.3, p.131; description (after Popta).

Nomenclature

Osteochilus repang was described by Popta (1904) from a single specimen. The holotype is the only known specimen, but the species has unique characters which distinguish it from other species.

Diagnosis

D. IV,16; l.l. 32; c.f. 12/2/14; c.p. 16; g.r. 24 (approx.)

O. repang has a uniform brown color on the body, three tubercles on the front of the snout, and a long dorsal fin (16 branched rays)

O. repang shares some characters with *O. borneensis* such as many of the body proportions, the long dorsal fin, and the tubercles on the snout. *O. repang* has larger scales (32 scales in lateral line), but *O. borneensis* has small scales (47-49 scales in lateral line).

Description

Body oblong, deep, and compressed; depth 442 (in thousandths of standard length). Head 231; eye 49; snout 96, with three pointed tubercles in the front, the middle one largest and lateral ones smaller; snout longer than postorbital part of head. Interorbital space 146, slightly convex. Mouth subinferior, two pairs of well developed barbels; maxillary barbels about equal to eye diameter, rostral barbels much shorter than the maxillary ones. Ventral surface of upper lip consists of well developed short costae. Predorsal length 420; origin of dorsal fin opposite 9th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin with normal height, the length of the fourth simple ray 279, and the base of dorsal fin 420, branched dorsal rays 16. The insertion of the dorsal fin opposite 23rd scale of lateral line, number of scales from posterior base of dorsal fin to vertical from anal fin origin is −1. Tip of pectoral fin not reaching the pelvic fin insertion, and opposite the eighth scale of lateral line. Prepelvic length 522; pelvic fin insertion opposite 12th scale of lateral line. Preanal length 763; anal fin origin opposite 22nd scale of lateral line. Caudal fin deeply forked, its lobe more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 18; least depth of caudal peduncle 154, greater than its length and surrounded by 16 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales 11; circumferential scales 12/2/14, transverse scales (to the base of pelvic fin) 6/1/5. Lateral line scales 32 with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch approximately 24.

The holotype is dark brown; the dorsal part of the head is darker than the rest of the body. Coloration of the body is uniform.

Distribution

Only one specimen known from River Bo, left branch of the superior Mahakam, Central Borneo.

Habitat

Unknown

Material examined (1 specimen 192.1 mm standard length)

Table 21 Proportional measurements of *O. repang* (measurements expressed as thousandths of standard length)

Characters	type
Depth	442
Head	231
Eye	49
Snout	96
Interorbital space	146
Base of dorsal fin	420
Fourth simple dorsal ray	279
Predorsal length	441
Prepelvic length	522
Preanal length	763
Third simple anal ray	237
Pectoral fin length	217
Pelvic fin length	232
Depth of caudal peduncle	154
Length of caudal peduncle	118
Lateral line scales	32
Predorsal scales	11
Circumferential scales	12/2/14
Transverse scales (to the base of pelvic fin)	6/1/5
Circumpeduncular scales	16
Dorsal branched rays	16

Pectoral rays	15
Gill rakers	24(app.)
Maxillary barbel	80
Rostral barbel	51

Osteochilus borneensis (Bleeker)

Rohita borneensis Bleeker, 1857: p.17; original description; type locality: Borneo (Kapuas River at Pontianak); type specimen BMNH 1866.5.2.173; total length 80 mm. (given by Bleeker), 62.8 mm. standard length (my measurement).

Rohita (Rohita) borneensis Bleeker, 1863: vol.3, p. 63; description; locality (same as above); with color plate.

Osteochilus borneensis Gunther, 1868: vol.6, p.41; description, locality (from Bleeker's specimen).

Osteochilus borneensis Weber & de Beaufort, 1916: vol.3, p.133; description, locality: Sumatra (Si-Djandjung, Djambi), Borneo (Kapuas River, Pontianak, Smitau and Mandai River).

Nomenclature

Osteochilus borneensis was described from a single specimen by Bleeker in 1857 and was redescribed again in 1863 in his Atlas, refering to the same specimen. Bleeker's type specimen was purchased by the British Museum and was redescribed by Gunther in 1868. After 1900, a number of specimens had been collected which confirmed the validity of this species.

Diagnosis

D. IV,16-19; l.l. 41-49; c.f. 17-19/2/17-20; c.p. 22-24

O. borneensis has several unique characters and is easily recognized. It has small scales (l.l. 41-49) as does *O. melanopleura* (l.l 45-53), but there is a difference in the mouth structure and circumferential scales. *O. borneensis* has a normal subinferior mouth with short divided mound-shaped costae arranged in regular rows (fig. 46), while *O. melanopleura* has an ascending mouth, with mound-shaped costae which are irregularly arranged (fig. 47). The circumferential scale formula of *O. borneensis* is

17-19/2/17-20, while it is 22-23/2/23-24 in *O. melanopleura*.

Description

Body oblong, deep, and compressed; depth 334-380 (mean=360) (in thousandths of standard length). Head 200-276 (mean=234); eye 42-78 (mean=62), large fish with relatively small eye. Snout 66-96 (mean=82); usually with three pointed tubercles in the front, the middle one the largest and lateral one small or rudimentary; snout longer than eye diameter in adult fish, shorter than interorbital space, about equal to the postorbital part of head. Interorbital space slightly convex, 101-138 (mean=125). Mouth subinferior, two pairs of well developed barbels; maxillary barbels about equal to eye diameter, rostral barbels much shorter than the maxillary ones. Ventral surface of upper lip consists of well developed, short, mound-shaped costae (fig. 46). Predorsal length 428-447 (mean=442); origin of dorsal fin opposite 9th to 13th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually of normal height, length of the fourth simple ray 228-276 (mean=255)' and the length of dorsal fin base 351-420 (mean=370), branched dorsal rays 16-19. The insertion of the dorsal fin opposite 31st-35th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from -2 to 0. Tip of pectoral fin not reaching the pelvic fin inserion, usually opposite 10th - 13th scale of lateral line. Prepelvic length 515-540; pelvic fin insertion opposite 15th -17th scale of lateral line. Preanal length 738-792 (mean=776); anal fin concave, third simple ray rather weak; anal fin origin opposite 30th-34th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 102-140 (mean=122); least depth of caudal peduncle 127-138 (mean=134) usually greater than its length, and more than half of head length; length of caudal peduncle 102-140 (mean=112). Caudal peduncle is surrounded by 22-24 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales usually 13-16; circumferential scales 17-19/2/17-20 (8.5-9.5/1/5-6.5 in transverse series to the base of pelvic fin). Lateral line scale 41-49 with three additional pored scales on the caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 28-31.

Preserved specimens are dusky on the anterior part of the body; the dorsal part of head and back are darker. Several narrow faint bands (15-17) along side of the body, more distinct on bottom half of the body. A large round black spot on caudal peduncle. Dorsal, pectoral and caudal fin densely pigmented with dark melanophores on the fin membranes, other fins plain.

Distribution

O. borneensis is definitely known only from Borneo and Sumatra (most specimens were collected from the Kapuas River). Bleeker (1865) reported this species from Thailand on the basis of a drawing by Catelnau contained in an album of Thai fishes. None of the existing specimens is from Thailand. Therefore, Catelnau's drawing might be inaccurate, might not be based on a Thai specimen, or might have been misidentified by Bleeker. Smith (1945) gave examples of many species which were contained in Catelnau's drawings which were certainly not Thai. The locality stated as "Siam" in Weber and de Beaufort (1916) was after Bleeker (1865).

Habitat

Large or small streams, probably prefering turbid waters.

Material Examined (14 specimens, 62.8-282.0 mm. in standard length)
Holotype:BMNH 1866.5.2.173, Pontianak, Kapuas River, Borneo.

Other specimens:
Borneo: PMNH 85-177-3-1 (2 spec.)
PMNH 85-177-3-2 (1 spec.)
RMNH 7676 (1 spec.) Nangah Rahoen

RMNH 7675 (2 spec.) Kapuas River at Semitau

KCTR 76-16 (2 spec.) Sungai Tekam (tributary of Kapuas).

KCTR 76-17 (1 spec.) Small forest stream, tributary of Kapuas.

KCTR 76-33 (1 spec.) Kapuas main stream at Selimbau

Sumatra: ZMA 116.062 (1 spec.) no specific locality

ZMA 116.063 (1 spec.)no specific locality

AMNH 9492 (1 spec.) Djambi

Table 22 Proportional Measurements of *O. borneensis* (measurements expressed as thousandthss of standard length)

Characters	type	others (n=14)	
		mean	S.D(n-1)
Depth	346	360	15.39
Head	276	234	26.05
Eye	75	62	13.24
Snout	86	82	9.41
Interorbital	119	125	9.18
Base of dorsal fin	368	370	18.84
Fourth simple dorsal ray	255	255	11.86
Predorsal length	398	443	10.10
Prepelvic length	520	532	9.07
Preanal length	779	776	25.7
Anal fin height	213	215	12.2
Pelvic fin length	204	210	9.1
Pectoral fin length	203	207	7.1
Depth of caudal peduncle	127	134	7.2
Length of caudal penduncle	115	122	11.2
Lateral line scales	42+3	44.8	1.7
Predorsal scales	16	14.4	1.2
Circumferential scales			
Transverse scales			
Circumpeduncular scales	22	22.5	0.9
Dorsal branched rays	17	16.8	1.0

Pectoral rays	16	15.5	0.5
Gill rakers	22	22.0	1.96
Maxillary barbels	92	70	19.6
Rostral barbels	33	41	11.8

Osteochilus schlegeli (Bleeker)

Rohita schlegeli Bleeker, 1851: p.432; original description; type locality; Bandjermassing (Southern Borneo); single type specimen 120 mm. total length (given by Bleeker) is not available.

Rohita (Rohita) schlegeli Bleeker, 1860: p.169; redescription.

Rohita (Rohita) schlegeli Bleeker, 1863: vol.3, p.65; redescription, 11 additional specimens; locality: Sumatra (Meninju, Palembang, Lahat); Borneo (Bandjermasin, Prabukarta, Pontianak); with color plate.

Osteochilus schlegeli Gunther, 1868: vol.7, p.42; description; 1 spec. from Bleeker's collection, 1 specimen from Leyden Museum; both with no locality; 1 specimen from Siam.

Osteochilus schlegeli Sauvage, 1881: p.163; 1883: p.152; locality: Siam, Menam Chaophya.

Osteochilus schlegeli Weber and de Beaufort, 1916: vol.3, p.129; description; locality:Sumatra (Palembang, Djambi); Borneo (Djonkong).

Osteochilus schlegeli Smith, 1945: p.216; locality:Thailand, Chaophya River at Angtong; Maeklong River at Ban Pong.

Nomenclature

Osteochilus schlegeli was described by Bleeker in 1851 from a single specimen of 120 mm. total length. In his 1863 Atlas 11 additional specimens were listed as 71 mm to 258 mm. total length. In 1868 Gunther claimed that specimen no. BMNH 1866.5.2.166 from Dr. Bleeker's collection is the type of the species but I have examined this specimen and itis 173.8 mm. in standard length (216 mm T.L.). It is, therefore, not possible for it to be the holotype. There are no specimens in RMNH indicated as a type and none of the specimens from Bleeker's collection of this species have a label of specific locality. I cannot locate the real type specimen and it is probably lost. The species has unique characters and there are no foreseen taxonomic problems with it; therefore, I do not intend to designate a neotype.

Diagnosis

D. IV,13-14 (rarely 12); l.l. 32-33; c.f. 13/2/15; c.p. 20.

Osteochilus schlegeli is a large fish which grows to more than 300 mm (S.L.). It has a unique number of circumpeduncular scales (20) except for *O. kalabau* which sometimes has 20 circumpeduncular scales. The body is plain except that young specimens usually have a black vertical blotch on the side above pectoral fin which lies across the fifth scale of the lateral line and the one scale above and the one below. Some specimens of *O. schlegeli* have a large black spot on the anterior base of the dorsal fin. This character is shared with *O. triporus* and *O. intermedius*, but the latter two species have a more slender body and 16 circumpenduncular scales. *O. schlegeli* shares some characters with *O. melonoplura* and *O. kalabau* such as the structure of the lip (with irregular round-shaped costae) and a deep body but *O. schlegeli* has a much shorter dorsal fin and fewer circumferential scales.

Description

Body oblong, deep, and compressed; depth 340-433 (mean=375) (in thousandths of standard length). Head 213-280 (mean=247); eye 58-88 (mean=68), large fish with relatively small eye, center of the eye on the lower half of head. Snout 60-93 (mean=78), entire, no tubercles or pores on the tip; snout longer than eye diameter in adult fish, shorter than interorbital space, and shorter than the postorbital part of head. Interorbital space slightly convex 134-159 (mean=145). Mouth subinferior, two pairs of well developed barbels; maxillary barbels usually shorter than eye diameter, rostral barbels much shorter than the maxillary oness (slightly more than 1/2 length of maxillary barbels). Ventral surface of upper lip consists of well developed irregular round mound shaped costae. Predorsal length 420-510 (mean=450); origin of dorsal fin opposite 8th-10th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually high, the length of the fourth simple ray 252–344 (mean=292), and the base of dorsal fin 274–346 (mean=315); branched dorsal rays 13–14 (rarely 12). The insertion of the dorsal fin usually opposite 21st–22nd (rarely 19th or 20th) scale of lateral line, number of scales from insertion of dorsal fin to vertical from anal fin origin varies from 0 to 2. Tip of pectoral fin usually not reaching the pelvic fin insertion, usually opposite 9th to 10th (rarely 8 or 11th) scale of lateral line. Prepelvic length 457–504 (mean=487); pelvic fin insertion opposite 9th–11th scale of lateral line. Preanal length 744–780 (mean=764); anal fin concave, third simple ray rather weak; anal fin origin opposite 21st–23rd scale of lateral line. Caudal fin deeply forked; its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 119–164 (mean=141); least depth of caudal peduncle 121–158 (mean=142), longer than half of head length and surrounded by 20 scale rows. Scales with nearly parallel longitudinal radii, predorsal scales usually 11 (may be 10 or 12); circumferential scales 13/2/15, transverse scales to the base of pelvic fin 6.5/1/5.5. Lateral line scales 32–33 with two additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly, its scales with simple tubes. Gill rakers on the first gill arch 24–30 (mean=28.5).

Preserved specimens are dusky on the upper fifths of the side; the dorsal part of the head and the back are a little darker. The main part of the body is uniformly plain pale brownish-yellow. Most young specimens have a vertical blotch on the 5th scale of the lateral line and one scale above and one scale below the lateral line, above the middle portion of th specimens have a large black spot on the anterior base of the dorsal fin. All other fins lack pigmentation.

Distribution

The distribution of *O. schlegeli* is separated into two disjunct areas: the northern range is central Thailand (lower Chao Phya river and Me Klong River), and the southern range is Malaysia, Sumatra, and Borneo.

Habitat

Large rivers with slow current and turbid water.

Material Examined (46 speciemens, 66.4 mm.-313.7 mm standard length)

Bleeker's Collection: BMNH 1866.5.2.166 (1 spec.) no locality
: RMNH 6992 (5 spec.) no locality.
: BMNH (without no.) (1 spec.)
indicated from Layden Museum;
no locality (107.3 mm S.L.)

Borneo :RMNH 1767 (2 spec.) no specific locality
:RMNH 2594 (3 spec.) no specific locality
:RMNH 2595 (1 spec.) no specific locality
:RMNH 282 (2 spec.) no specific locality
:ZMA 116.061 (1 spec.) Djongkong (Eastern Borneo)
:KCTR 76-19 (1 spec.) Sintang Market
:KCTR 76-44 (1 spec.) Sungai Tawang near Danau
Pengembung, tributary of Kapuas.

Sumatra :ZMA 116.060 (3 spec.) Palembang
:ZMA 116.059 (1 spec.) Batang Hari River,
Djambi
:ZMA 116.058 (2 spec.) Djambi
:AMNH 9297 (1 spec.) Batang Hari River, Djambi
:UMMZ 155573 (1 spec.) Palembang Market.

Thailand :BMNH 1898.4.2.180-187 (7 spec.) Chao Phya River
:MHNP 85-177-35-2 (8 spec.) Bangkok
:MHNP 85-177-35-1 (2 spec.) no specific locality

:ZMA 116.057 (1 spec.) Chao Phya River near Angtong

:NIFI (uncatalogue) (2 spec.) Ayuthaya

Table 23 Proportional Measurements of *O. schlegeli* (measurements expressed as thousandthss of standard length)

Characters	mean	S.D.(n=46)
Depth	375	20.0
Head	247	14.5
Eye	68	7.9
Snout	78	7.0
Interorbital	145	6.1
Base of dorsal fin	315	18.1
Fourth simple dorsal ray	291	18.1
Predorsal length	450	40.7
Prepelvic length	487	20.5
Preanal length	764	15.4
Anal fin height	230	13.2
Pelvic fin length	247	12.7
Pectoral fin length	217	10.2
Depth of caudal peduncle	142	6.4
Length of caudal penduncle	141	12.7
Lateral line scales	32.7	0.7
Predorsal scales	11.10	0.6
Circumferential scales	13/2/15	
Transverse scales	6.5/1/5.5	
Circumpeduncular scales	20	
Dorsal branched rays	13.5	0.6
Pectoral rays	15.6	0.7

		188
Gill rakers	28.5	2.7
Maxillary barbels	48	9.3
Rostral barbels	27	5.5

Osteochilus kalabau Popta

Osteochilus kalabau Popta, 1904: p.196; original description; type locality: River Bo, Borneo; Holotype, RMNH 7578, 218 mm., total length (given by Popta), 200.6 mm. standard length (my measurement).

Osteochilus Kalabau Popta, 1906: p.99; description (referring to the same specimen).

Osteochilus kalabau Weber and de Beaufort, 1916: vol.3, p 128; description; locality: Batu Panga, Mahakam River; Borneo.

Nomenclature

O. kalabau was described by Popta in 1904 from a single specimen. Besides the holotype (RMNH 7578), only two additional specimens had been collected during Weber and de Beaufort's studies. Although there are only three specimens available for this study, this species is unique and easily recognized. *O. kukenthali* is probably a junior synonym of this species (see page 186).

Diagnosis

D. IV,16; l.l. 35; c.f. 16-17/2/16-17; c.p. 17-18

O. kalabau has a large blackish vertical blotch on the side of the body above the pectoral fin, large scales (35 in lateral line) and a long dorsal fin (D. IV,16). Mouth ascending, ventral part of upper lip with round mound-shaped costae.

O. kalabau shares many features with *O. melanopleura* such as a large blackish blotch, an ascending mouth, similar lip strucutures, and the long dorsal fin, but *O. melanopleura* has much smaller scales (45-53 in lateral line).

Description

Body oblong, deep, and compressed; depth 330-398 (in thousandths of standard length). Head 236-252; eye 54-68; large fish with relatively small eye. Snout longer than eye diameter in adult fish but shorter than interorbital space, a shorter than postorbital part of the head. Interorbital space slightly convex, 140-157. Mouth ascending, two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed irregular round mound-shaped costae. Predorsal length about 438; origin of dorsal fin opposite 9th or 10th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually falcate, its fourth simple ray greatly produced but shorter than base of dorsal fin; the length of the fourth simple ray 309-356, and the base of dorsal fin 349-364; branched dorsal rays 16. The insertion of the dorsal fin opposite 25th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from -1 to 0. Tip of pectoral fin reaching the pelvic fin insertion, usually opposite 11th to 12th scale of lateral line. Prepelvic length about 486; pelvic fin insertion opposite 11th-12th scale of lateral line. Preanal length about 791; anal fin concave, third simple ray rather weak; anal fin origin opposite 24th-25th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 133-140; least depth of caudal peduncle 140-157, greater than half of head length, and also greater than its length, surrounded by 22 scale rows. Scales with parallel longitudinal radii, predorsal scales 13-14; circumferential scales 16-17/2/16-17 (8-8.5/1/5.5-6 in transverse series); lateral line scales 34-35 with three additional pored scales on caudal base. Lateral line somewhat straight but slightly curved upward anteriorly. Its scales with simple tubes, gill rakers on the first gill arch 29-34 .

Preserved specimens are dark brown, the dorsal part of the head and the back are darker than the rest of the body. There is a large blackish vertical blotch above the pectoral fin at 5th and 6th scale of lateral line, extending two rows above and four rows below the lateral line. According to Popta's description, the body and fins are violet-red, darker above and yellowish-violet below.

Distribution

River Bo, River Mahakam and its tributaries, Central and Eastern Borneo.

Habitat

Unknown

Material Examined (3 specimens 94.3–200.6 mm. standard length)

Holotype :RMNH 7578, River Bo, Borneo

Other specimens:

ZMA 116.056 (2 spec.), Batu Pangal,
Mahakam River, Borneo.

Table 24 Proportional Measurements of *O. kalabau* (measurements expressed as thousandthss of standard length)

Characters	type	other specimens 1	2
Standard length (mm)	200.6	179.9	94.3
Depth	398	330	382
Head	242	236	251
Eye	57	54	68
Snout	84	77	87
Interorbital	157	140	148
Base of dorsal fin length	360	364	349
Fourth simple dorsal ray	356	346	309
Predorsal length	438		
Prepelvic length	486		
Preanal length	791		
Anal fin height	275		252
Pelvic fin length	251	262	243
Pectoral fin length	235	233	223
Depth of caudal peduncle	157	145	140
Length of caudal pendunclе	133	134	140
Lateral line scales	34	34	35
Predorsal scales	13	13	14
Circumferential scales			
Transverse scales			
Circumpeduncular scales	17	18	18

Dorsal branched rays	16	16	16
Pectoral rays	18	18	18
Gill rakers	34		29
Maxillary barbels	78	76	62
Rostral barbels	64	103	72

Osteochilus melanopleura (Bleeker)

(fig. 20)

Rohita melanopleura Bleeker, 1852: p.430; original description; type locality: Bandjermassing, Borneo, and Palembang Sumatra; Syntypes (3 specimens) 126 mm–320mm total length (given by Bleeker), BMNH 1866.5.2.212 (1 spec.) 101.6 mm standard length, RMNH 6990 (2 spec.) 103.1, 238.9 standard length (my measurement).

Rohita (Rohita) melanopleura Bleeker, 1860: vol.2, p.40; description; locality: Kahajan, Pontianak, Borneo. ---1863: vol 3,p 62; description; same locality.

Osteochilus melanopleura Gunther, 1868: vol.7,p.40; description; one type specimen from Bleeker's collection, and one specimen from Thailand.

Osteochilus melanopleuras Fowler, 1905: 479; description; locality: Kapuas River, Borneo, Baram River in Sarawak.

Osteochilus melanopleuras Weber & de Beaufort, 1916: vol 3, p.127: description; locality: Palembang, Djambi in Sumatra.

Osteochilus melanopleurus Smith, 1945: 212; locality: Peninsula Thailand, central Thailand at Mekong River and Chao Phya River, Mawang at Lampang, and Manam Mun northeastern Thailand.

Nomenclature

Osteochilus melanopleura was described from three specimens from Sumatra and Borneo in 1852. The original locality label of the syntypes may have been lost and it is impossible to tell which specimens came from where. This species was designated as the type species of the genus by Jordan (1919), which he selected as the first name in the species list in Gunther (1868). This species has unique characters and is easy to recognize. There are no anticipated systematic problems for this species, and therefore, I choose not to designate a lectotype.

Diagnosis

D.IV. 16–18; l.l.41–53; c.f. 22–23/2/23–24; c.p. 22–24

O. melanopleura can be distinguished by the small scales (41–53 in lateral line), an ascending mouth, and a large blackish vertical blotch on the side of body above the pectoral fin. Snout entire; ventral part of upper lip with round mound shaped costae arranged in irregular rows, gill rakers on the first gill arch 27–35.

O. melanopleura shares many characters with *O. kalabau* such as the blotch above the pectoral fin, the ascending mouth, and a long dorsal fin; however, *O. kalabau* has larger scales (32–33 lateral line scales, c.f 16–17/2/16–17).

O. borneensis is the only other species that has small scales (l.l. 47–49), but it has a subinferior mouth and it does not have a blotch above the pectoral fin.

Description

Body oblong, deep, and compressed; depth 310–405 (mean=376) (in thousandths of standard length). Head 224–297 (mean=262); eye 44–93 (mean=63); large fish with relatively small eye. Snout 83–110 (mean=94), entire, without tubercles; snout longer than eye diameter in adult fish, shorter than interorbital space, shorter than postorbital part of the head. Interorbital space slightly convex, 127–157 (mean=145); mouth ascending. Two pairs of well developed barbels; maxillary barbels longer than eye diameter, rostral barbels shorter than the maxillary ones. Ventral surface of upper lip consists of well developed, irregular, round mound-shaped, costae. Predorsal length 421–458 (mean=443); origin of dorsal fin opposite 11th or 14th scale of lateral line, before mid-point between tip of snout and caudal base and also before the pelvic fin insertion. Dorsal fin usually falcate, its fourth simple ray greatly produced, but shorter than base of dorsal fin, the length of the fourth simple ray 221–329 (mean=228), and the base of dorsal fin 285–402 (mean=372); branched dorsal rays 16–18. The insertion of the dorsal fin opposite 30th to 37th scale of lateral line, number of scales from insertion of the dorsal fin to vertical from anal fin origin varies from −3 to −1. Tip of pectoral fin reaching the pelvic fin insertion, usually opposite 12th to 15th scale of lateral line. Prepelvic length 478-452 (mean=506); pelvic fin insertion opposite 13th-17th scale of lateral line. Preanal length 743-780 (mean=764); anal fin concave, third simple ray rather weak, anal fin origin opposite 28th-34th scale of lateral line. Caudal fin deeply forked, its lobes more or less acute, upper lobe slightly longer than the lower lobe. Length of caudal peduncle 102-153 (mean=132); least depth of caudal peduncle 129-154 (mean=138), greater than half of head length, and also greater than its length, surrounded by 22 to 26 scale rows. Scales with parallel longitudinal radii, predorsal scales 15-22; circumferential scales 22-23/2/23-24 (11-11.5/1/11.5-22 in transverse series to the base of the pelvic fin); Lateral line scales 41-53, with three additional pored scales on the caudal base. Lateral line somewhat straight but slightly curved upward anteriorly; its scales with simple tubes. Gill rakers on the first gill arch 25-35 (may exceed 40 in the specimens larger than 200 mm SL)

Preserved specimens are greyish brown, the dorsal part of the head and back are darker. A large blackish vertical blotch is on the side above the middle part of the pectoral fin. Fresh specimens are dark gray above and light gray below, dorsal and caudal fins with melanin pigment, other fins plain.

Distribution

O. melanopleura has a wide distribution but is restricted to the low elevations. Smith (1945) states that there are no records of this species from the mountain regions of northern and western Thailand. The range of *O. melanopleura* extends from Borneo, Sumatra, Java, and Malay Peninsula northwest to central and northeastern Thailand as far as the Mekong Basin and its tributaries (Laos, Cambodia, and South Vietnam).

Habitat

On the mainland of Southeast Asia, *O. melanopleura* is always found in large rivers or lakes which have slow moving waters. Turbid waters are preferred but the specimens collected by Dr. Tyson Roberts from Borneo (KCTR 76-20, KCTR 76-49) are both from swift current and clear water.

Material Examined (164 specimens, 70.9-365.7 mm standard length) Syntype: BMNH 1866.5.2.212 (1 spec.) no locality RMNH 6990 (2 spec.) Banjermassin or Palembang

Other specimens:

No locality: RMNH 9247 (6 spec.) from Bleeker's collection

Borneo: RMNH 2593 (1spec.) no specific locality
MHNP 85-177-24-8 (1spec.) no specific locality
MHNP 85-177-24-9 (1 spec.) no specific locality
KCTR 76-20 (3 spec.) lower part of Sungai Kebian, tributary of Kapaus
KCTR 76-49 (1 spec.) Sungai Djentawang, 37-38 km N.E. of Sintang.
ANSP 72241 (1 spec.) Kapuas River
ANSP 72240 (1 spec.) Baram River

Sumatra: MHNP 85-177-24-10 (1 spec.) no specific locality
ZMA uncatalogued (3 spec.) Djambi
ZMA uncatalogued (1 spec.) Palembang
USNM 93286 (1 spec.) Mandan River at Siak

Malysia: NMS 1954 (2 spec.) Poloh Nering, Kalantan
NMS 1883 (1 spec.) Chenderoh Dam, Perak

Thailand: AMNH 14597 (1 spec.) Tapi River at Bandon
ZSI 10514/1 (3 spec.) Nontaburi & Bangkok
AMNH 14574 (1 spec.) Meklong River at Banpong
USNM 71012 (1 spec.) Mekong River
USNM 103257 (1 spec.) Meyom at Lampang

USNM 103258 (1 spec.) Menam Mun at Ta Charng

UMMZ 201072 (1 spec.) Nam Pong Reservior

UMMZ 201068 (3 spec.) Huay Hin Tack, Bandon, Ubol

UMMZ 201069 (2 spec.) Lam Pao Reservior, Kalasin

UMMZ 201071 (1 spec.) Lam Pao Reservior, across Ban Kok Kang

UMMZ 102067 (1 spec.) Mun River at Bandan, Ubol UMMZ 201074 (1 spec.) Mun River at 3 km downstream from Ubol. UMMZ 201070 (4 spec.) Huay Kwang, S. of Khong Chiam, Ubol. UMMZ 201073 (1 spec.) Mun River, 1.3 km upstream from Ubol UMMZ 201075 (1 spec.) Mun River, 3 km downstream from Ubol UMMZ 195729 (3 spec.) Mun River, 20 km downstream from Ubol UMMZ 195094 (1 spec.) Chao Phya River at Nakorn Sawan UMMZ 195680 (3 spec.) Market at Ubol UMMZ 195273 (10 spec.) Meklong River at Rajburi ANSP 89367 (7 spec.) Bangkak ANSP 60327-28 (2 spec.) Bangkok ANSP 60804-7 (4 spec.) Bangkok ANSP 57560 (1 spec.) Bangkok NIFI uncatalogued (20 spec.) Ubolratana Reservior, N.E. Thailand NIFI uncatalogued (15 spec.) Ubolratana Reservior, N.E. Thailand NIFI uncatalogued (8 spec.) Hauy Luang, Udorn NIFI uncatalogued (12 spec.) Mekong River at Nong Kai NIFI uncatalogued (9 spec.) Mekong River 100 km East of Nong Kai NIFI uncatalogued (7 spec.) Chao Phya River at Ayuthya NIFI uncatalogued (10 spec.) Ubol market

Cambodia: UMMZ 181249 (2 spec.) Great Lake at Kampong

Table 25 Proportional measurements of *O. melanopleura* (measurements expressed as thousandths of standard length)

Characters	3 syntype	other specimens	
	mean	mean	S.D.(n=161)
Depth	380	375	24.9
Head	270	262	18.3
Eye	54	63	12.0
Snout	98	94	7.3
Interorbital space	147	145	5.9
Base of dorsal fin	359	373	24.4
Fourth simple dorsal ray	302	288	25.3
Predorsal length		443	15.7
Prepelvic length		506	16.2
Preanal length		764	13.7
Third simple anal ray	255	254	20.0
Pectoral fin length	221	222	15.3
Pelvic fin length	252	247	16.4
Depth of caudal peduncle	142	138	6.3
Length of caudal peduncle	121	132	13.1
Lateral line scales	41–48	46.5	2.5
Predorsal scales	16–19	17.9	1.3
Circumferential scales			
Transverse scales			
Circumpeduncular scales	23–24	22–24	
Dorsal branched rays	16–18	17.1	0.7

Pectoral rays	17–18	16.9	0.8
Gill rakers	29–40	30.9	3.2
Maxillary barbel	95	88	21.0
Rostral barbel	73	68	15.3

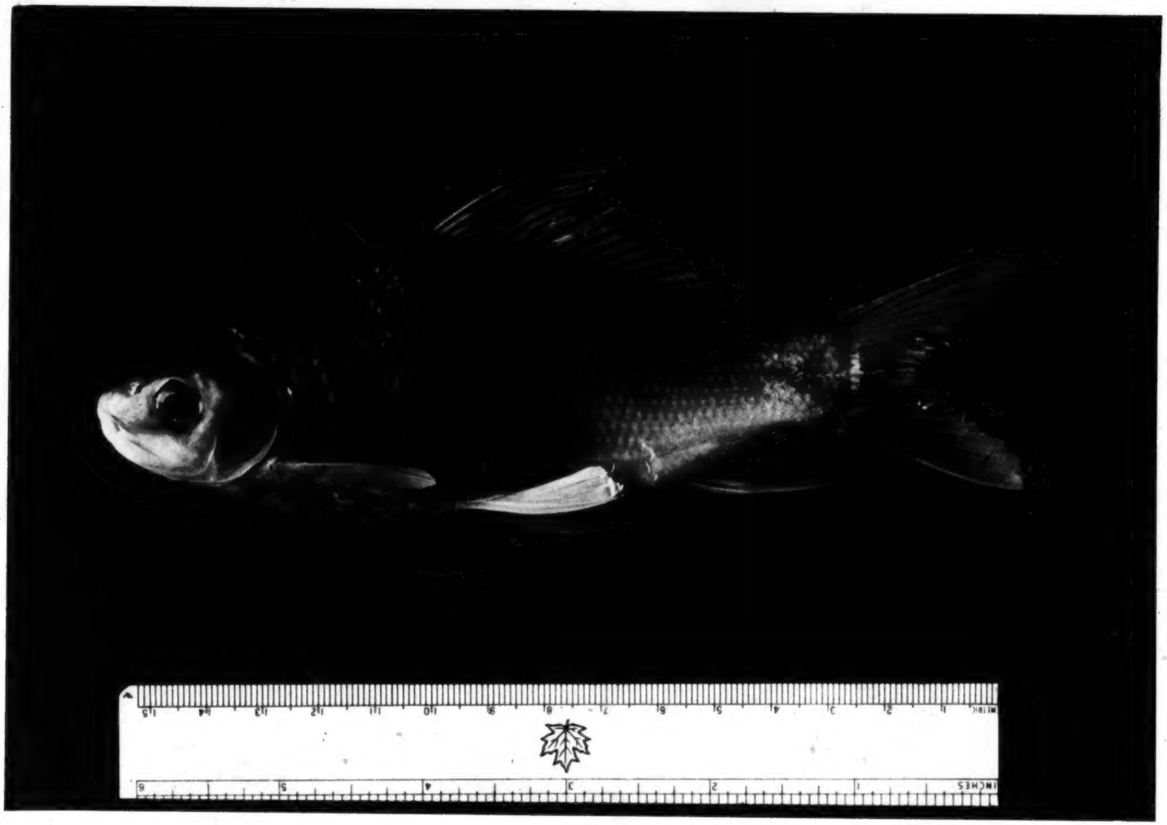

Fig. 20 Osteochilus melanopleura (Bleeker)

SPECIES OF *OSTEOCHILUS*

WITH

UNCERTAIN STATUS

SPECIES OF *OSTEOCHILUS* WITH UNCERTAIN STATUS

Osteochilus vittatus (Valenciennes)

Rohita vittatus Valenciennes in Cuvier and Valenciennes, 1842: vol.16, p.203; original description: type locality Java; holotype: MHNP 85-177-44-1; five inches total length (given by Valenciennes), 94.2 mm standard length (my measurement).

Diagnosis (counts and measurements taken from holotype)

D.IV,14; p.13; A.III,5; l.l.32-33; c.f.11/2/13; c.p.16; p.d.10; g.r.25.

Depth 350; head 219; eye 66; snout 69; interorbital space 118; length of caudal peduncle 149; base of dorsal fin 294; last simple dorsal ray 240.

Discussion

The *Osteochilus vittatus* that was described in 1842 by Valenciennes (in Cuvier and Valenciennes, 1842) is not the same species as the *O. vittatus* that is popularly recognized. The original description is very superficial and does not diagnose the species. The holotype (MHNP 85-177-44-1) from Java has 14 branched dorsal rays. It is in very bad condition, scales are left only on the posterior half of the body, and the specimen is soft and spoiled. I could not see a stripe or any other pattern on the body, and the specimen does not have tubercles or pores on the snout. In Cuvier and Valenciennes's (1842) original description, it was called Le Rohite a Bandes" (= striped Rohita), and their description does not mention a single stripe but nine brown lines or bands are said to be present.

The *O. vittatus* that we recognize now is based on Bleeker's publication (mainly the 1863 Atlas with a color plate), and it is not the same species as Valenciennes's *O. vittatus.* Weber & de Beaufort (1916) stated: "The above description is in accordance with that of Bleeker given for *Rohita vittatus*; the description of Cuvier & Valenciennes is too superficial to be sure that it is the same as Bleeker's species." Bleeker's *O. vittatus* has 11–12 branched dorsal rays and a single median lateral stripe.

Bleeker's *O. vittatus* is the same as *O. microcephalus* (Cuv. & Val.,1842), of which two syntypes exist (RMNH 2115, 2116). Although these syntypes are dry mounted specimens, they are in good condition and readily identifiable. Therefore, the valid name for the *O. vittatus* of Bleeker and of current usage is *O. microcephalus* (Cuv. & Val.). The status of *O. vittatus (Val.) is still doubtful, it is possibly close to O. hasselti*, *O. sarawakensis* or *O. harrisoni*, but the two latter species are restricted to the northern part of Borneo (Sarawak) and have never been recorded from Java; more collections are needed to confirm the status of this species.

Osteochilus kukenthali Ahl

Osteochilus kukenthali Ahl, 1922: p.33; original description; type locality Mahakam Kutei, southeast Borneo; syntypes: Mus. Berol. Pisc. (Germany) cat.no. 20537 (not seen) (2 specimens) 8.3 and 10.1 cm total length (given by Ahl).

Diagnosis (counts and measurements based on the original description)

D. IV,15–16; P. 16–18; A. III,5; l.l. 36; c.f. 17/2/17; transverse scales 8.5/1/5.5 to the base of pelvic fin; c.p. 18

Depth 2 2/3 in standard length, 3 3/4–3 4/5 in total length; head 3 1/3–3 1/2 in standard length, 4 1/2 – 4 3/4 in total length; eye 3–3 1/3 in head, 1 5/6–2 in interorbital width, depth of caudal peduncle two in head.

Lower jaw is slightly ascending. Origin of dorsal fin opposite 10th scale of lateral line; predorsal scales arranged irregularly, about 24–27; the first ray of dorsal fin elongated, its height a little shorter than head. Origin of anal fin opposite the 24th scale of lateral line, still under the dorsal fin. Pelvic fin origin is opposite the 12th scale of lateral line. Caudal fin deeply forked, much longer than head but less than the body height.

Body color is brownish-silver, the back is a darker brown. A large black spot on the caudal peduncle : black blotch on some scales above the middle part of pectoral fin, above and below the lateral line.

Discussion

Ahl (1922) comments at the end of his description that this species is intermediate between *Osteochilus kalabau* Popta and *O. schlegeli* (Bleeker), but closer to the former species. The only difference between *O. kalabau* and *O. kukenthali* stated by Ahl is the arrangement of the predorsal scales. I feel that this character is a poor one to use to separate the species, since I found many individuals of other species with an irregularly arrangement of predorsal scales, especially in species from Borneo. From the distribution of other characters, I believe that this species is probably *O. kalabau*, but the type specimen of this species should be examined.

Osteochilus *melanopterus* Tirant

Osteochilus melanopterus Tirant, 1929: p.27 (see also p.153); original description; type locality: rivers in Hue, Vietnam; type specimen: Lyon, France? (not seen).

Diagnosis (counts and measuements from original description)

D. IV,14; A. III,5; l.l.28 (to the last scale); c.f. 13/2/13

Body silvery white with 9 to 11 black longitudinal stripes; with four barbels; all fins with black border.

Discussion

Tirant (1929: p.27) gave a very short description. He did not describe the mouth so it is uncertain whether this species belongs to *Osteochilus*. Tirant (1929: p.153) gives a slightly different description of this species in stating "all fins blackish; tip of ventral fin dark black." I presume that this species is variable in coloration of the fins. If this species belongs to *Osteochilus* and if the counts (cited above) are correct it presumably is a valid species.

SPECIES IMPROPERLY ASSIGNED

TO *OSTEOCHILUS*

16 SPECIES

(four species names are considered *nomina nuda*)

SPECIES IMPROPERLY ASSIGNED TO *OSTEOCHILUS*

Dangila lipocheila Valenciennes

Dangila lipocheila Valenciennes in Cuvier and Valenciennes, 1842: vol. 16, p. 176-177; original description; type locality Java; type specimen not available, no illustration.

Dangila lipocheila Bleeker, 1863: vol. 3, p. 48, plt. 7, fig. 1; description and comment (probably not *D. lipocheila*)

Dangila lipocheila Gunther 1868: vol.7, p.40; comment.

Osteochilus lipocheilus Fowler, 1976: p.47; list of species of *Osteochilus*

Discussion

The type specimen of *Dangila lipocheila* was lost and the original description does not diagnose the species. The original description states that the specimen has eight branched dorsal rays and 36 lateral line scales; it does not, therefore, belong in our concept of *Osteochilus* or *Dangila*. Bleeker says that this name was first given by Kuhl and Van Hasselt to a fish which they had drawn and which he (Bleeker) had copied; it would appear to have 18 branched dorsal rays and 32 lateral line scales. Bleeker thinks that it has been confused by Valenciennes with *Barbichthys leavis*, with which his description agrees better, than with the *D. lipocheilus* of Kuhl and Van Hasselt. Gunther (1868) considers that it possibily belongs to *Osteochilus* (species of *Dangila* (=Labeobarbus) have more than 20 branched dorsal rays). The status of this species is not certain and it is impossible to establish to what species it should be applied. Therefore, I consider this species to be a *nomen nudum*.

Cyrene cyanopareja Heckel

Cyrene cyanopareja Heckel, 1843: p.1025; description; type locality : Philippine Islands; type specimen not seen (probably lost), no illustration.

Cyrene cyanopareja Gunther, 1868: vol.7, p.40; footnote

Osteochilus cyanopareja Fowler, 1976: p.46; list of species of *Osteochilus*

Discussion

The species was poorly described in 1843 by Heckel. According to the original description this species has 17 branched dorsal rays and 35 scales along the lateral line. It is probably an *Osteochilus*, but *Osteochilus* has never been recorded from the Philippines. At this stage it is not possible to determine the status of this species. If the type specimen of this species is lost, this name should be considered a *nomen nudum*.

Osteochilus malabaricus Day

Osteochilus malabaricus Day, 1873: p.527; original description; type locality; Vithry, in the Wynaad, India; no type specimen, no illustration.

Discussion

Osteochilus malabaricus as described by Day (1873) has 11 branched dorsal rays; 44 scales on the lateral line, and 8/1/8 scales in transverse series (to the mid abdominal point). Day also stated "neither lip fringed; no horny substance over lips or inside the lower jaw". From this statement in the original description, it is clear that this fish does not belong to *Osteochilus* . Day (1876) considered the close similarity of *O. malabaricus* to *Scaphiodon nashi* but did not think that they were the same species. Mukerji (1932) states for the name *O. malabaricus* ".....in all probability this is a misnomer.

Day does not seem to have called anything by this name". As the species was allied to *Scaphiodon* by Day (1876), and Hora (1942) used this alignment to place some species of *Scaphiodon* into *Osteochilus* (see page 202). *O. malabricus* was poorly described and no type specimen is available, therefore, I consider this name to be a *nomen nudum*.

Rohita simus Sauvage

Rohita sima Sauvage 1878: p.238; original description; type locality: Phnom-Penh, Cambodia; no type specimen, no illustration.

Rohita sima Sauvage 1881: p.177; description; locality: Mekong and Phnom-Penh.

Osteochilus sima Fowler 1935: p.117; description; locality Srisawat, Thailand. (not *Rohita sima*)

Osteochilus simus Smith 1945: p.219; comment

Osteochilus simus Fowler, 1976: p.49; list of species of *Osteochilus*

Discussion

The type specimen of *Rohita simus* is lost. The original description very poorly diagnoses the species (D.IV, 16; A.III, 5; l.l.48, only rostral barbels, fringed upper lip and lower lip). The type specimen is lost and it is impossible to assign the name to any species. Therefore, I consider this species to be a *nomen nudum*. My examination of the specimens that Fowler (1935) identified as *Osteochilus sima* shows that it is *Cirrhinus macrosemion* (Fowler).

Labeo chrysophekadian (Bleeker)

(as senior synonym of *Rohita barbatula* Sauvage)

Rohita barbatula Sauvage, 1878: p.239; original description; type locality: Mekong River at Phnom-Penh, Cambodia; holotype MHNP 85-124 (dry mounted specimen), 374.9 mm standard length (my measurement); paratype 85-124-31-1 (alc. specimen), 110.3 mm standard length (same data).

Rohita barbatula Sauvage, 1881: p.176, plt.5, fig3; description; locality Mekong, Phu-Quoc(Gulf of Siam), Phnom-Penh, Tong-heu(province of Bien-Hoa, Vietnam)

Osteochilus barbatulus Fowler, 1976: p.45; list of species of *Osteochilus*

Diagnosis (counts and measurements taken from the types of *Rohita barbatula*).

D. IV,17; p.17; A. III,5; l.l. 37-39; c.f. 17-18/2/17; c.p. 22; p.d. 15-16; g.r. 55.

Depth 294; head 270; eye71; snout 93; interorbital space 139; length of caudal peduncle 155; depth of caudal peduncle 127; base of dorsal fin 313; last simple dorsal ray 303.

Discussion

The examination of the type specimens of *Rohita barbatula* revealed that this species does not belong to *Osteochilus* as was indicated by Fowler (1978).The mouth structure of *Rohita barbatulas* is not the same as that of *Osteochilus*. This species was compared to the type specimen of *Labeo chrysophekadian*, and found to agree with this species. Therefore, *Rohita barbatulas* is a junior synnonym of *Labeo chrysophekadian*.

Labeo chrysophekadian (Bleeker)

(as a senior synonym of *Rohita pectoralis* Sauvage)

Rohita pectoralis Sauvage, 1878: p.238; original description; type locality: Phnom-Penh; Holotype MHNP 85-124-31-3, 119.4 mm standard length (my measurement)

Rohita pectoralis Sauvage, 1881: p.178, plt.8, fig.1; description; locality Phnom-Penh, Cambodia.

Osteochilus pectoralis Fowler, 1976: p.48; list of species of *Osteochilus*

Diagnosis (counts and measurments taken from the holotype of *Rohita pectoralis*)

D. IV, 6; p.17; A. III,5; l.l.38; c.f.18/2/17; c.p.22; p.d.16; g.r. approx. 57.

Depth 418; head 258; eye 68; snout 91; interorbital space 149; length of caudal peduncle 152; depth of caudal peduncle 134; base of dorsal fin 298, last simple dorsal ray 256.

Discussion

Sauvage described *Rohita pectoralis* and *Rohita barbatulas* at the same time on the basis of differences in the number of lateral line scales with 38 in *R. barbatula* and 46-48 in *Rohita pectoralis*. I examined type specimens of both species and did not find such a difference (38 in *R.pectoralis* and 37-39 in *R. barbatula*). This species is so similar to the type specimen of*Labeo chrysophekadian* (RMNH 12364), that I consider it to be a junior synonym of *L. chrysophekadian*.

Labeo cephalus Valenciennes

Labeo cephalus Valenciennes in Cuvier and Valenciennes 1842: vol. 16, p. 374; fig. 487; original description; type locality: Irrawaddi River at Rangoon, Burma; syntypes (2 specimens) MHNP 85-124-34-1, 253.0, 250.6 mm standard length (my measurement).

Labeo cephalus Gunther 1868: vol. 7, p. 40; comment on the species.

Osteochilus cephalus Day 1876: p. 546; description; locality Pegu, Burma.

Osteochilus cephalus Day 1889: vol. 1, p. 275; description; locality Pegu.

Osteochilus cephalus Fowler, 1976: p. 46; list of the species of *Osteochilus*

Diagnosis (counts and measurements taken from syntypes)

D. IV, 13; p. 17; A. III, 5; l.l. 37-39; c. f. 13/1/13; c. p. 18; p. d. 13; g. r. 86.

Depth 323-326; head 249-264; eye 54-55; snout 72-76; interorbital space 175-181; length of caudal peduncle 134-154; depth of caudal peduncle 140-142; base of dorsal fin 235-250; last simple dorsal ray 235-250.

Discussion

Labeo cephalus was described by Valenciennes in 1842 in the genus *Labeo*. Gunther (1868), in a footnote, evidently considered this species to be in *Osteochilus*. He did not see the specimen and he came to this decision on the basis of Valenciennes's original description. Day (1876, 1889) placed the species under the genus *Osteochilus*, probably on the basis of Gunther's comment. The examination of the type specimens of *Labeo cephalus* confirmed the placement of this species in the genus *Labeo*.

Labeo curchius (Hamilton)

(as a senior synonym of *Rohita chalybaetas* Valenciennes)

Rohita chalybaeta Valenciennes in Cuvier and Valenciennes 1842: vol. 16, p. 206; original description; type localty: Rangoon, Burma; holotype: MHNP 85-124-35-3, 91.7 mm standard length (my measurement)

Labeo chalybaetus Gunther 1868: vol 7, p. 60; description, locality Rangoon.

Osteochilus chalybaetus Day 1876: p. 545, plt. 79, fig.1;description; locality: Moulmein, Burma

Osteochilus chalybaetus Day 1889: vol1, p.273; description; locality: Irrawaddy and Salween river in Burma.

Osteochilus chalybaetus Fowler, 1976: p46; list of species of *Osteochilus*

Diagnosis (counts and measurements taken from the holotype of *Rohita chalybaetus*).

D. IV,14; P. 16; A. III,5; l.l. 60; c.f. 23/2/23; c.p. 26; p.d. 23; g.r. 53.

Depth 281; head 254; eye 78; snout 74; interorbital space 135; length of caudal peduncle 129; depth of caudal peduncle 128; base of dorsal fin 266; last simple dorsal ray 263.

Discussion

Rohita chalybaetas was described by Valenciennes in 1842 and was placed in *Labeo* by Gunther (1868); he considered the genus *Rohita* to be a junior synonym of *Labeo* . Day (1876,1889) considered the genus *Rohita* to be a junior synonym of *Osteochilus*. Day placed this species in *Osteochilus* because his specimen had 18 branched dorsal rays, 54 scales in the lateral line (total number), and 8/1/10 in transverse series (to the mid-abdominal point); these counts show that Day's specimen is not the same species as *Rohita chalybaetas* Cuv.& Val.. An examination of the type specimen shows that *Rohita chalybaetas* is a junior synonym of *Labeo curchius* (Hamilton, 1822).

Cirrhinus chinensis Gunther

(as a senior synonym of *Osteochilus prosemion* Fowler)

Osteochilus prosemion Fowler, 1934: p. 116, fig 66,67; original description; type locality: Meping River at Chiengmai, Northern Thailand; holotype ANSP 59095, 91.3 mm standard length (my measurement); and paratypes ANSP 59096-7 (two specimens), same data, 85.4-89.4 mm standard length (my measurement)

Osteochils prosemion Fowler, 1937: p.183; locality: Mekong River at Kamarat, N.E. Thailand.

Osteochilus prosemion Smith, 1945: p.218; description

Diagnosis (counts and measurements taken from the type specimens of *O.prosemion*)

D. IV,11-12; P. 17-18; A. III, 5; l.l. 37-38; c.f. 15/2/17; c.p. 18-20; p.c. 12-14.

Depth 266-285; head 211-213; eye 53-58; snout 66-75; interorbital space 87-93; length of caudal peduncle 14.3-16.6; depth of caudal peduncle; 11.2-12.2; base of dorsal fin 21.4-24.5; last simple dorsal ray 24.2-27.2; only rostrol barbels present.

Body plain silvery, with large vertical blotch on the side above pectoral fin, all fin plain and hyaline.

Discussion

Fowler described a few species of *Osteochilus* from fishes belonging to the genus *Cirrhinus* on the basis of their having fringed lips. *Osteochilus prosemion* is one of three species; it was described in 1934 and belongs to *Cirrhinus chinensis*. This species has a wide distribution (from China to Southeast Asia) and has been introduced to many places in Asia for food culture. The species is also known by the name *Cirrhinus molitorella* (or *Labeo molitorella* Weber& de Beaufort 1916: p 213, Smith 1945: p. 33), but Banarescu 1972 considered the name *C. molitorella* (Valenciennes) a *numen nudum* and recognized *C. chinenses* as the valid name for the species.

Cirrhinus macrosemion (Fowler)

Osteochilus macrosemion Fowler, 1935: p. 116; original description; type locality: Kwai Yai River at Srisawat, western Thailand; Holotype ANSP 60809, 185 mm total length (Fowler's measurement), 139.6 mm standard length (my measurement).

Osteochilus macrosemion Smith 1945: p. 218; diagnosis and comment on the species.

Diagnosis (counts and measurements taken from the holotype)

D. IV,15; P. 17; A. III,5; l.l. 35; c.f. 15/2/17; c.p. 20; p.d. 11

Depth 330; head 197; eye 62; snout 57; interorbital space 102; length of caudal peduncle 138; depth of caudal peduncle 123; base of dorsal fin 292; last simple dorsal ray 360; gill rakers on the first gill arch 72; only one pair of barbels (rostral) present.

Body coloration plain; a black vertical blotch on the side above the middle part of the pectoral fin. Dorsal fin with darkish margin, other fins plain.

Discussion

O. macrosemion was described by Fowler in 1935. This species is closely related to the previous species (*Cirrhinus chinensis*) but has a longer dorsal fin and fewer lateral line scales. *O. macrosemion* has one pair of barbels (rostral) and the structure of the lips shows that it belongs to *Cirrhinus*. *O. macrosemion* and *O. spilopleura* were described at the same time and the specimens were collected from the same locality. The species was regarded by Fowler as "apparently distinct" from *O. spilopleura,* by having no pores on the snout and a prolonged last simple ray of the dorsal fin. From my examination of the type specimens I found that both species bear pores (tubercles) on the snout; other characters are identical except for the elongation of the last simple dorsal ray of *O. macrosemion* which has little taxonomic importance. Apparently they are the same species and belong to the genus *Cirrhinus*. The species should be recognized as *Cirrhinus macrosemion*.

Cirrhinus macrosemion (Fowler)

(as a senior synonym of *Osteochilus spilopleura* Fowler)

Osteochilus spilopleura Fowler, 1935: p.115,fig.52,53; original description; type locality: Kwai Yai River at Srisawat; Western Thailand; Holotype: ANSP 101604, 213 mm total length (Fowler's measurement), 154.7 mm standard length (my measurement).

Osteochilus spilopleura Smith 1945: p218; locality: Mesoi, a tributary of Mewang, north of Lampang.

Diagnosis (counts and measurments taken from holotype of *O. spilopleura*)

D. IV,15; P.17; A. III,5; l.l. 35; c.f. 15/2/17; c.p. 20; p. d. 12. Depth 348; head 210; eye 59; snout 73; interorbital space 108; length of caudal peduncle 145; depth of caudal peduncle 124; base of dorsal fin 293; last simple dorsal ray 279; gill rakers on the first gill arch 70; only one pair of barbels (rostral) present.

Body coloration plain; a large vertical blotch above on the side above pectoral fin; all fins plain.

Discussion

This species is a junior synonym of *Cirrhinus macrosemion* (see the discussion of the previous species).

Labeo dyocheilus (McClelland)

(as a senior synonym of *Osteochilus ochrus* Fowler)

Osteochilus ochrus Fowler, 1935: p. 118, fig. 56,57; original description; type locality: Bangkok, Thailand; holotype: ANSP 61781, 130 mm total length (given by Fowler), 96.1 mm standard length (my measurement)

Osteochilus ochrus Fowler, 1937: p.180; locality: Kemarat, N.E. Thailand.

Osteochilus ochrus Smith, 1945: p. 217; comment on the species.

Diagnosis (counts and measurements taken from the holotype of *Osteochilus ochrus*).

D. IV,11; P. 17; A. III,5; l.l. 40; c.f. 18/2/17; c.p. 22; p.d. 12

Depth 302; head 239; eye 66; snout 88; interorbital space 115; length of caudal peduncle 162; depth of caudal peduncle 132; base of dorsal fin 214; last simple dorsal ray 281; gill rakers on the first gill arch numerous, but partly damaged, unable to count; one pair of barbels (maxillary), small and concealed in the post labial groove; snout with numerous small tubercles.

Upper surface of head and body olive and grayish; dorsal part of head and back are darker than sides. Faint lateral gray band, forming more definite dark gray diffuse spot at caudal base. Dorsal and caudal fins grayish, other fins hyaline.

Discussion

Fowler (1935) did not explain why he placed this species in *Osteochilus*. The type specimen has one pair of short flat barbels (maxillary) hidden in the post larbial groove. The structure of the lips, barbels, small scales, and numerous gill rakers show that it is *Labeo dyocheilus* a species common in Thailand.

Tylognathus behri (Fowler)

(as a senior synonym of *Osteochilus tatumi* Fowler)

Osteochilus tatumi Fowler, 1937: p. 180, fig. 118, 119; original description; type locality: Bangkok, Thailand; holoype ; ANSP 68095, 117 mm total length (Fowler's measurement), 82.6 mm standard length (my measurement).

Osteochilus tatumi Smith, 1945: p.217; comment on the species

Diagnosis (counts and measurement taken from the holotype of *Osteochilus tatumi*)

D. IV,13; P. 20; A. III,5; l.l. 35-36; c.f. 19/2/19; c.p. 20; p.d. 14.

Depth 286; head 255; eye 55; snout 73; interorbital space 97; length of caudal peduncle 181; depth of caudal peduncle 136; base of dorsal fin 252; last simple dorsal ray 284; gill rakers on the first gill arch 49; one pair of barbels (maxillary), concealed in the post labial groove.

Back brown, the color on the sides and below is faded to whitish. Two small dark brown or dusky spots at the scales immediately above and below the fifth scale of the lateral line. Diffuse grayish blotch or at caudal base. Dorsal fin dusky with dark anterior edge, caudal fin also dusky, other fins hyaline.

Discussion

Fowler (1937) described and placed this species under *Osteochilus* because it is similar to *O. ochrus* (=*Labeo dyocheilus*), a species which he described in 1935. From my examination of the lips (and other characters: scales, gill rakers, barbels, and color pattern) of the type specimen, I conclude that this species belongs to *Labeo behri* Fowler (= *Tylognathus behri*).

Labeo *dyocheilus* (McClelland)

(as a senior synonym of *Osteochilus sondhi* Hora & Mukerji)

Osteochilus sondhii Hora and Mukerji, 1934: p. 359, fig.2 a, b; original description; type locality: Salween River at Takaw in the Kengtung State, Burma; holotype: ZSI F11600/1, 118.7mm standard length (my measurement); paratype: same cat. no. (does not belong to the same species, see text.), 104.4 mm standard length (my measurement).

Diagnosis

Holotype: D. IV,12; p. 19; A. III; 5; l.l. 39; c.f. 17/2/17; c.p. 22; p. d. 14; g.r. damaged, unable to count (small and numerous). Depth 295; head 222; eye 53; snout 8.5; interorbital space 114; length of caudal peduncle 180; depth of caudal peduncle 132; base of dorsal fin 213; last simple ray 213.

Paratype: D. IV,11; P. 17; A. III,5; l.l. 38; c.f. 16/2/17; c.p. 20; p.d. 13; g.r. damaged, unable to count (small and numerous). Depth 278; head 221; eye 54; snout 74; interorbital space 84; length of caudal peduncle 153; depth of caudal peduncle 126; base of dorsal fin 207; last simple dorsal ray 228.

Discussion

Hora and Mukerji (1934) described *Osteochilus sondhi* from two specimens, the figure is drawn from the specimen which I refer to as the holotype (Hora did not designate the holotype). The second specimen is superficially similar to the first but the structure of its mouth is completely different. The second specimen also has a transverse groove across the snout. I identify the first specimen as *Labeo dyocheilus* (McClelland, 1839), and the second as *Tylognathus almorae* (Chaudhuri, 1912).

Subgenera *Kantaka* and *Osteochilichthys*

Hora (1942) proposed two new subgenera of *Osteochilus: Kantaka* which contains one species (*Semiplotus brevidorsalis* Day, 1873), and *Osteochilichthys* which contains two species (*Scaphiodon thomassi* Day, 1877, and *S. nashi* Day, 1877). These three species apparently belong to subfamily barbinae and not related to *Osteochilus*, Therefore I exclude these three species from *Osteochilus* The systematic position of these three species is needed for further study, but it is beyond the scope of this thesis. *Kantaka* and *Osteochilichthys* are probably deserved the generic rank (in Barbinae).

OSTEOLOGY

AXIAL SKELETON

A. Osteocranium.

Olfactory region

Cartilage bones: paired **lateral ethmoids** (LE) and **preethmoids** (PE), and median, unpaired **ethmoid** (E). Dermal bones: median, unpaired **supraethmoid** (SE), **vomer(V), and rostral** (RO), and **paired nasals** (N).

The **lateral ethmoids** (LE, fig. 22, 25, 26) protrude well beyond the lateral margins of the cranium. Basally, each bone is triangular. On the anterior part there is a thick, curved ascending wall which connects with the supraorbital. Posteriorly it is connected with the anterior surface of the supraorbital and has a thin-walled extension which attaches to the outside of the orbitosphenoid in a synchondrosis. Dorsally, each lateral ethmoid is overlain by a frontal; ventrally, contact is made with the parasphenoid. The lateral ethmoids contact each other medially. Laterally, each bone has an anterior curved process which makes contact with the inner side of the lachrymal bone and a ventral process which is curved downward and supports the eye ball.

The **preethmoids** (PE, fig. 24, 26) are irregular ovate bones attached to the ethmoid and the vomer. They are covered by the cartilage which articulate with the autopalatines

The ethmoid (E, fig. 22) is under the supraethmoid and over the vomer. It separates the olfactory capsules of the two sides from each other. The anterior border of the bone has a median concave notch which articulates with the vomer anteriorly and with the preethmoid anterolaterally. Ventrally, the bone bears a deep depression with thick lateral borders; this depression is covered by the vomer. The posterolateral sides of the ethmoid articulate with the anterior edges of lateral ethmoids. Anterodorsally there is a small foramen separating the bone from the supraethmoid.

The supraethmoid has thin wing-like extensions posteriorly; the dorsal surface of the bone is smooth in appearance but the posterior border is rough and is covered by the frontals. Laterally, the bone is bordered by the nasals; there are lateral wings which are free and overhang the nasal pit.

The nasal (NS, fig. 21-24) is a very small, long, and thin bone. It lies above the olfactory capsule, in the notch formed at the posterolateral corner of the supraethmoid and the adjoining corner of the frontal. Along with the lateral wing of the supraethmoid, the nasal forms the roof of the nasal pit and the dorsal border of the two sides of the nostrils.

The kinethmoid (rostral) (RO, fig. 21, 22, 24, 25, 26) is a short columnar bone, situated vertically in front of the concave notch of the anterior part of the ethmoid. The dorsal surface bears a wedge-shaped groove and the ventral surface is round. It is connected by two ventral ligaments to the heads of the vomer and by a laterally extending ligament to the maxillary ascending process.

The prevomer (PV, fig. 25) is a thin quadrangular bone, lying on the ventral surface of the skull immediately in front of the parasphenoid and beneath the ethmoid. It forms the floor of the cavity which is covered dorsally by the ethmoid. The anterior border of the bone is concave and bears a thick horn-like process at each corner which articulates with the preethmoid. The posterior edge is convex and bears a notch in the middle. The posterolateral edge of the vomer attaches to the base of the lateral ethmoid while posteriorly it overlaps the anterior border of the parasphenoid.

Orbital Region

Cartilage bones: unpaired, median, **orbitosphenoid (OSP)**, paired, lateral, **pterosphenoids (PTS)**. Dermal bones: (all paired) **lachrymals (LA), suborbitals 2-5 (SO2-SO5), supraorbital (SPO),** and **frontals (F).**

The orbitosphenoid (OSP, fig. 22, 23, 25, 26) is a Y shaped bone (in cross section) supporting the anterventral part of the brain, situated behind the eye balls, and sandwiched between the frontal (dorsally) and the parasphenoid (ventrally). It consists of a vertical ventral piece forming a septum between the eye ball and a horizontal dorsal piece forming the floor of the cranial cavity. The anterior edge of the orbitosphenoid overlaps the lateral ethmoids by a wide synchondrosis while the posterior edge articulates with the paired pterosphenoid.

The **pterosphenoids** (PTS, fig. 22, 23, 25, 26) are a pair of irregular bones, each consisting of a horizontal basal piece and a vertical process arising from the dorsal surface of the basal piece. The ventral surface of each basal piece has a jagged surface. Each pterosphenoid is sutured with the orbitosphenoid anteriorly, with the prootic posteriorly, and with the autosphenotic posterodorsally. The suture between the pterosphenoid and prootic is interrupted by the foramen of the trigeminal nerve (V). The pterosphenoids are overlain by the frontals above; below, their edges extend to the lateral boundaries of the orbital foramen. Anterodorsally the inner lamella is molded around the base of the cartilaginous epiphyseal bar (fig. 26) forming a vertical process. Of the two most conspicuous forammina in the pterosphenoid, the anterodorsal one, partly hidden under the roof of the epiphysial bar, accommodates the ophthalmic branch of the facial nerve, and the more posteroventral one accommodates the ophthalmic branch of the trigeminal nerve.

The **lachrymal** (first suborbital) (LA, fig. 21) is an almost rectangular plate with a convex anteroventral margin, bearing two pores of the lateral line system at the anteroventral part of the bone. It lies over the anterolateral part of the ethmoid and below the nasal opening. It covers the lateral part of the palatine anteriorly and the anterior process of the lateral ethmoid posteriorly. The anterior end of the bone is attached by means of connective tissue to the maxillary bone.

The second suborbital is a flat plate expanded anteriorly and attached to the inner side of the lachrymal. It tapers posteriorly and connects to the third suborbital. The second suborbital borders the anteroventral half of the orbital, and bears two pores of the lateral line system.

The third suborbital (SO3, fig. 21) is curved, lamellated, and expanded in the middle part. There are two pores of the lateral line system. It borders the posteroventral quarter of the orbital before joining the fourth suborbital.

The **fourth suborbital** (SO4, fig. 21) is reduced to a canal tube and forms the posterior border of the orbit.

The fifth suborbital (SO5, fig. 21) is minute and also consists only of a canal tube. The fifth suborbital is contiguous with and lies at right angles to the postorbital process of the autosphenotic.

The **frontals** (F, Fig. 24) are the two large plates roofing the brain cavity and are exceeded in size only by the operculars. They occupy one-half of the dorsal surface of the skull and are irregular and overlapped to each other. The anterior margin of the frontal is slightly convex and overlies the posterior edge of the supraethmoid and the lateral portions of the nasal. Anteriorly, each frontal narrows gradually to the concavity bordering the mesial edge of the supraorbital bone, then abruptly to a point, in conformity with the sphenoseptal regions of the underlying lateral ethmoid. The frontals cover the upper edges of the lateral ethmoids, orbitosphenoid, pterosphenoids, and autosphenotics, and overlap the anterior edges of the parietals. The ventral surface of each frontal presents two well marked sphenoseptal ridges outlining the supraorbital canal tube forming the side wall of the cranial cavity; one of them is a low ridge lying beneath the posterolateral triangular projection, and along with the lateral process of the autosphenotic articulates with the frontal while the other is a high ridge which articulates with the upper margins of the pterosphenoids and orbitosphenoids and with the lateral ethmoid in front. The portion of the frontal internal to this high ridge forms the roof of the cranial cavity, while the portion of each frontal between the two ridges forms the roof of the orbit. A broad, shallow, transverse furrow crosses the two bones. This reflects the course of the underlying, cartilaginous epiphyseal bar, which restricts the dorsal expansion of the brain between the anterior and posterior frontanelle. Each frontal has a posterolateral notch which exposes the lateral temporal fossa, which is confined mostly to the dorsal aspect of the postorbital process of the autosphenotic. There is a junction of three canals at this notch: the supraorbital canal from the frontal, the suborbital canal from suborbital 5, and the postorbital canal from the supratemporal. Harrington (1955) notes that in "a considerable number of cyprinid genera the supraorbital canal does not join the suborbital canal." In all labeine species that I have examined these three canals are joined.

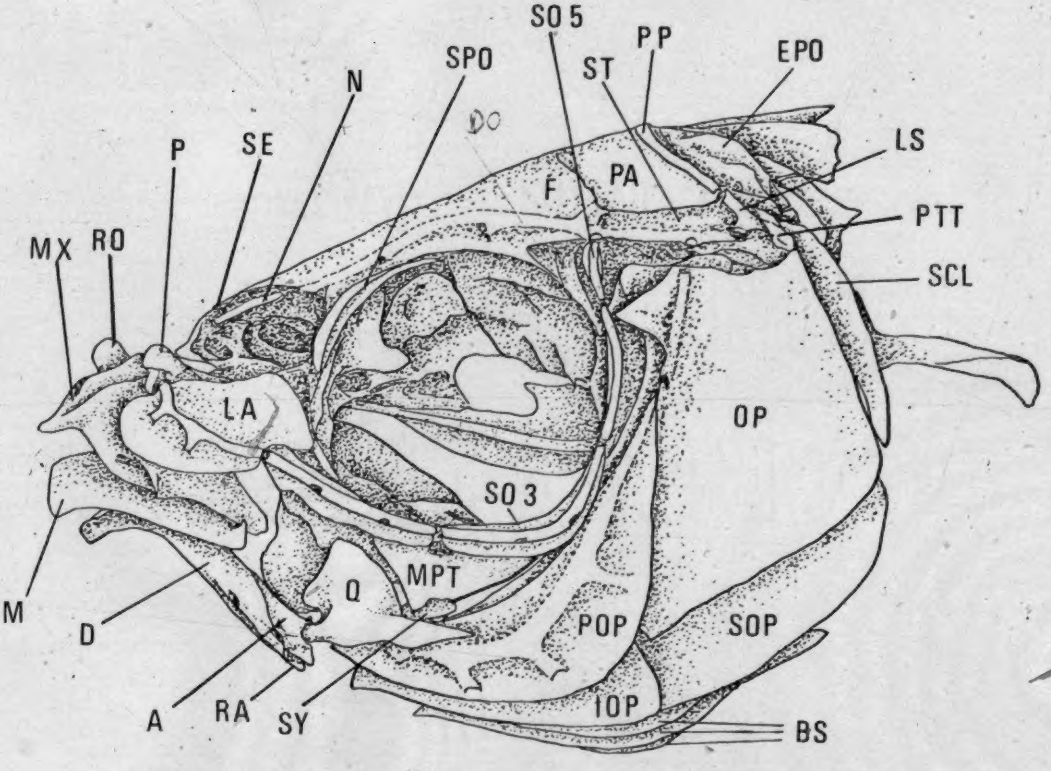
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Figure 21 Left lateral view of the intact skull of Osteochilus triporus

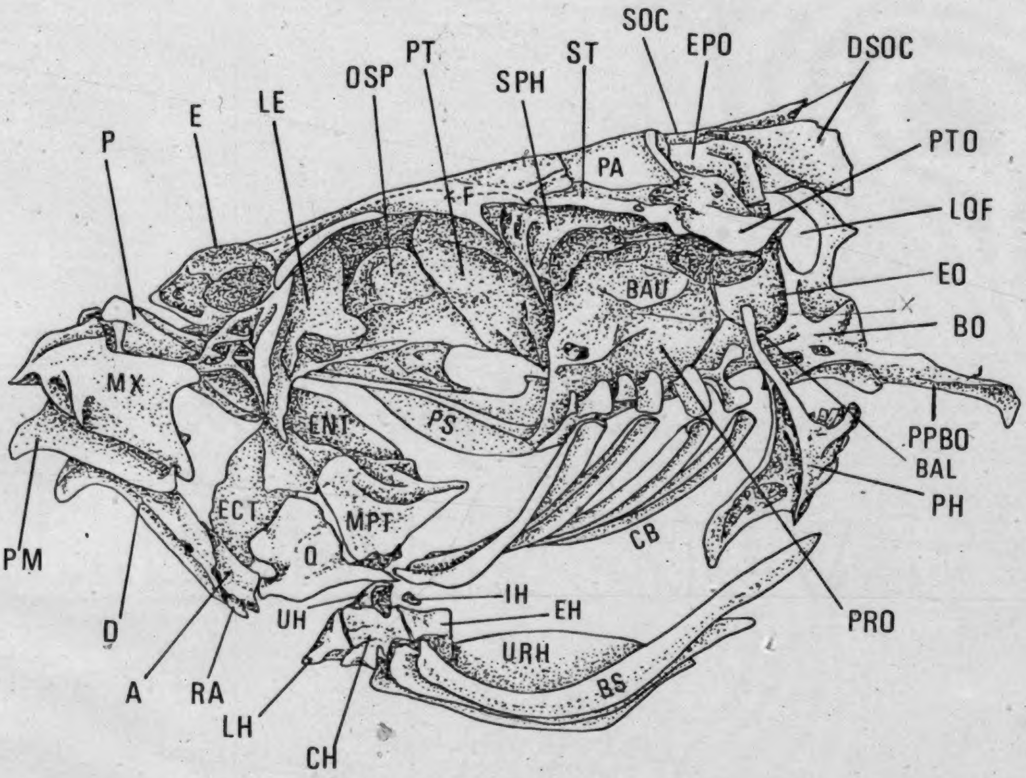
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Figure 22 Left lateral view of the skull of Osteochilus triporus, after removal of extrascapular, posttemporal, supracleithrum, suborbital series, opercular series, and hyomandibular.

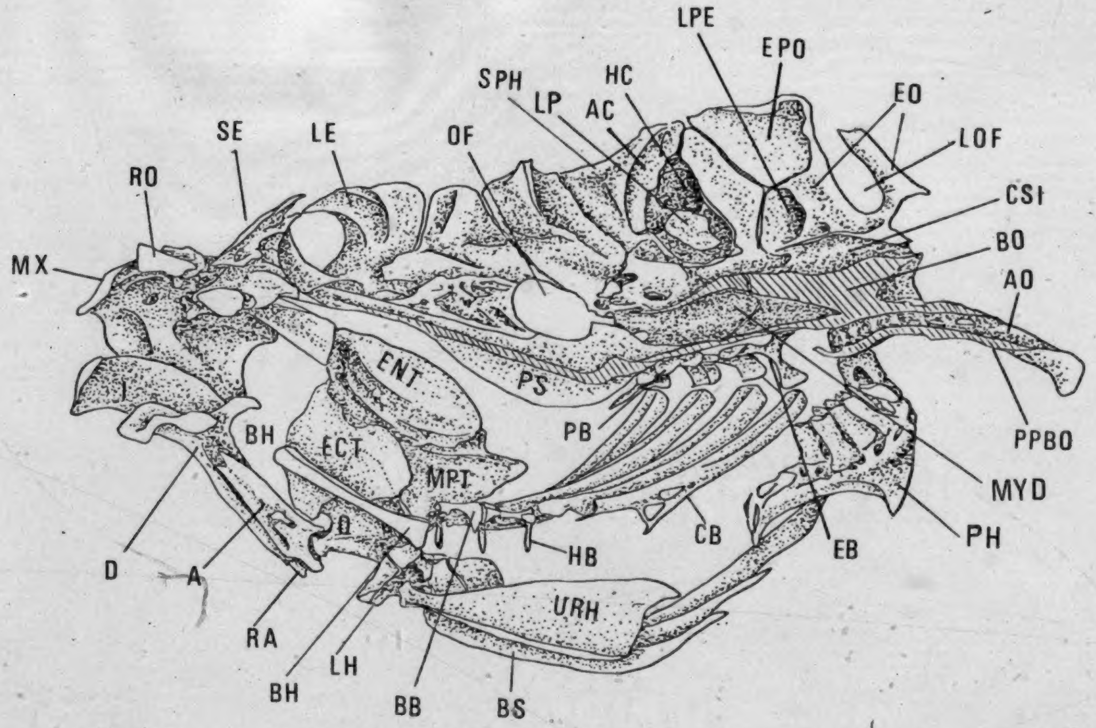
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Figure 23 Lateral view of the right half of the skull of *Osteochilus triporus*, after removal of frontals and parietal.

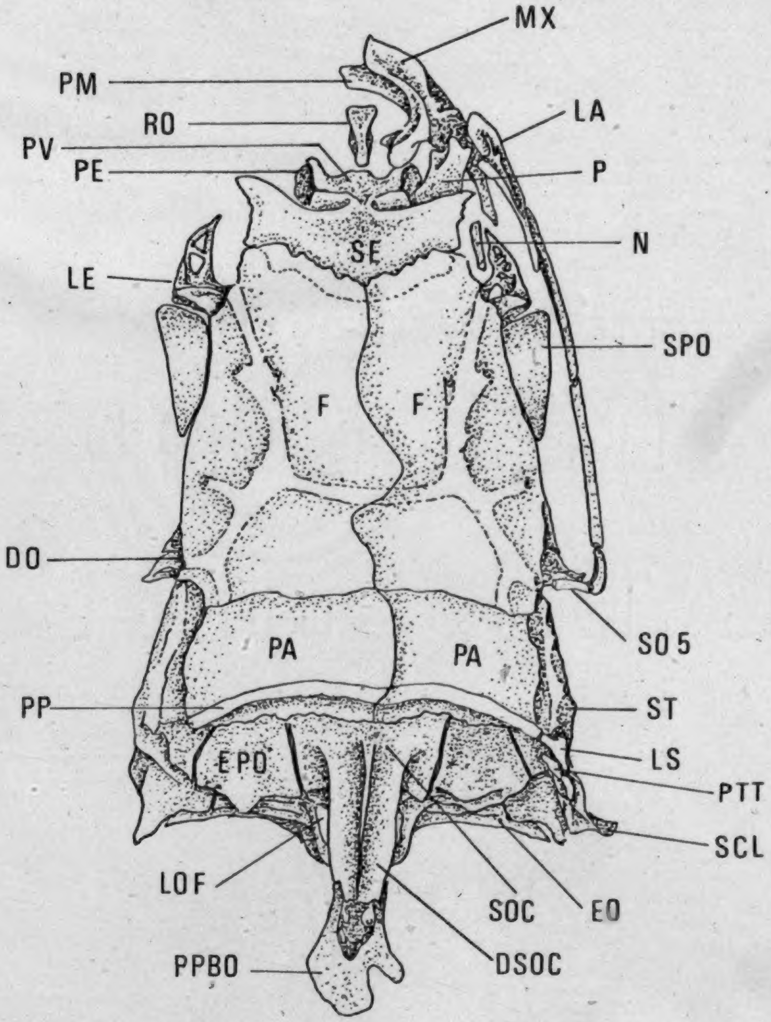
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Figure 24 Dorsal view of the skull of Osteochilus triporus, after removal of left posttemporal, left lateral extrascapular, left supracleithrum, left suborbital series, left oromandibular region, and left autopalatine.

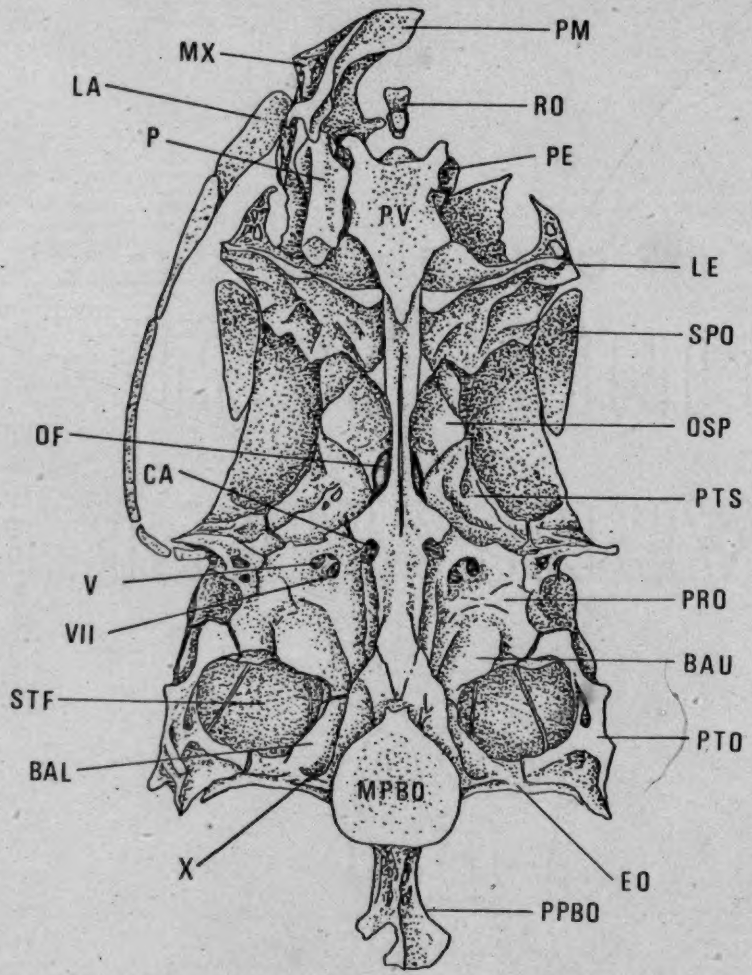
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Figure 25 Ventral view of the skull of Osteochilus triporus, after removal of the brachiocranium, lower and left side of the oromandibular region, and hyoid region.

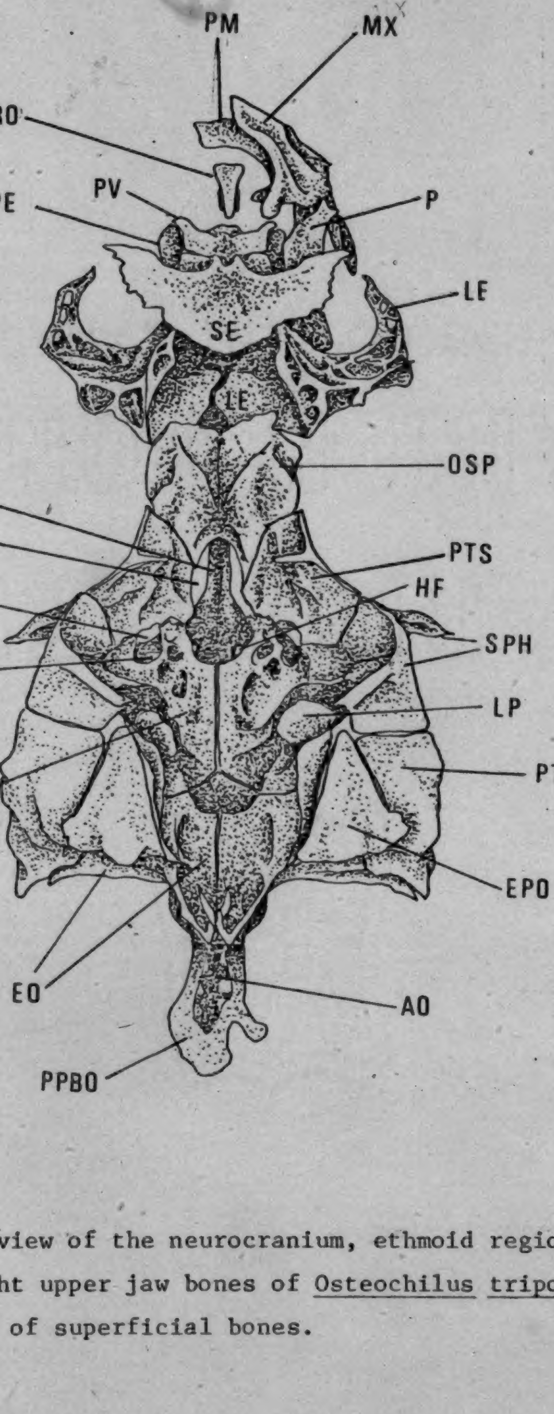
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Figure 26 Dorsal view of the neurocranium, ethmoid region, autopalatine, and right upper jaw bones of Osteochilus triporus, after removal of superficial bones.

The supraorbital (SPO, fig. 21, 24, 25) is quite large and is bordered anteriorly by the lateral ethmoid and lateroposteriorly by the frontals.

Otic Region

Cartilage bones: paired **autosphenotics (SPH), autopterotics (PTO), prootics (PRO), epiotics (EPO), opisthotics (OPIS), exoccipitals (EO),** unpaired **supraoccipital (SOC).** Dermal bones: paired **supratemporals (ST), parietals (PA),** medial **extrascapulars (PP), postemporals (PT), lateral extrascapulars (LS), supracleithra (SCL),** and unpaired **dermo-supraoccipital (DSOC)**

The cartilage bones of the otic region are widely separated by intervening cartilage. The main part of otic region, the auditory capsule, lies between the facial and the gossopharyngeal nerves.

The **autosphenotic** (SPH, fig. 22, 26) is sutured with the pterosphenoid anteriorly, with the prootic ventrally, and with the autopterotic posteriorly. Its upper edge contributes to the lateral margin of the posterior chondrocranial fontanelle. This margin is continued caudad by the mesial edge of a rhomboidal plate of cartilage, extending between the opposing upper edges of autosphenotics, autopterotic, epiotic, and supraoccipital. The autosphenotic is drawn out anterolaterally in a prominent postorbital process (fig. 25, 26), against which the mesial surface of the fifth suborbital rests, and the upper surface of which constitutes the lateral temporal fossa (DO, fig. 21, 24). [1]. The dorsal border of the autosphenotic is overlain anteriorly by the frontal and posteriorly by the parietal. Its posterior border is overlain laterally by the forward extension of the supratemporal. The autosphenotic forms the anterior boundary of the auditory capsule; the middle of the posterior border of the bone is traversed vertically by a broad, rounded ridge molded over the anterior semicircular canal (AC, fig. 23). A small mid-portion of this canal is excluded from the cranial cravity by the constriction of its mesial surface caused by two bone lamellae, which arise from the mesial surface of the autosphenotic on either side of the canal. There is a large depression on the lower edge (outer surface) of the autosphenotic extending to the hind portion of the autopterotic which contributes to the anterior facet for the hyomandibular.

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[1] Dilator operculi muscle origin

The **autopterotic** (PTO, fig. 22, 25) forms the posterolateral boundary of the auditory capsule. It forms a suture with the autosphenotic anteriorly, with the epiotic and exoccipital posteriorly, and with the prootic anteroventrally. The apex of its dorsal edge borders on the cartilage plate already mentioned. Its upper portion contributes to the surface of the skull externally and to the vault of the **subtemporal fossa** (STF, fig. 25). Internally, it forms a suture with a lamella of the epiotic, and ventrolaterally it encompasses the horizontal semicircular canal (HC, fig. 23), and rejoins its upper portion within the fossa, thus completely enclosing the canal and forming the outer margin of the fossa. In the intact skull, the entire dorsolateral surface of the autopterotic is covered by the lamellar portion of the supratemporal bone (ST, fig. 21, 22, 24) with which it is fused, so that only the inrolled lower margin and hindmost part of the autopterotic are visible.

The **epiotic** (EPO, fig. 21, 24, 26) encloses the posterior semicircular canal (LPE, fig. 23) and is situated posteriorly between the autopterotic and the exoccipital. It is a bowl-shaped bone which forms a suture with the autopterotic ventroanteriorly, with the exoccipital ventroposteriorly, and with the supraoccipital dorsomesially and, within the subtemporal fossa, ventromesially. Inside the fossa the anteromedial edge of the internal lamella of this bone, which forms the lateral and hind curvature of the fossa roof, is opposed to the posterolateral border of the prootic with which it is connected through the intervention of cartilage. This cartilage completes the fossa roof between these two bones and the autopterotic.

The **prootics** (PRO, figs. 22, 25, 26) are large irregular bones which form the antero-mesial wall of the auditory capsule and form a portion of the wall of the chamber housing the two anteriormost semicircular canals (one vertical and the other horizontal). The trigeminal foramen lies between the prootic and the autosphenotic (V, fig. 25, 26) with the autosphenotic and autopterotic dorsolaterally, with the exoccipital lateroposteriorly, and with the basioccipital posteriorly. A posterolateral extension forms the anteromedial curvature of the subtemporal fossa roof, and is connected here, between its surface with the autopterotic and exoccipital, with the opposing anteromedial edge of the inner lamellar layer of the epiotic by the cartilage just mentioned. The trigemino-facialis recess is on the anterior edge of the mesial surface of the prootic. This recess (between V and VII, fig. 25, 26) is bounded laterally by a bony ridge (between V and VII, fig. 25, 26) , separating the trigeminal notch from the facial foramen. On the external, ventrolateral aspect of the prootic, a prominent bulla acustica utricularis (BAU, fig. 22, 25) encloses the utricularis with its contained lapillus (fig. 27). The recessus utricularlis, on the inner surface of the bone opposite to the bulla, is separated from the rest of the inner surface by a ridge running diagonally from just behind the facial foramen toward the posteromedial angle of the bone. Ventromesially, the prootics split into lamellae for their entire length. The more extensive dorsal lamellae meet in the midline to form the prootic bridge over the posterior eye-muscle canal (**myodome**: MYD, fig. 23), which is also the floor of the leaving a gap between them, the hypophysial foramen (HF, fig. 26), through which the stalk of the hypophysis passes. The opposing ventral lamellae are shorter, and have a much longer gap between them, which is closed off ventrally by the parasphenoid. The parasphenoid forms the floor, and the dorsal and ventral lamellae of the prootics form, respectively, the roof and side walls of myodome which is open in front. Behind the prootic, the roof and side walls of the myodome are continued by the ventral surface of the basioccipital concave ventrally. The basioccipital forms the blind end of the myodome, which is enclosed ventrally by the posterior end of the parasphenoid. The hind end of each prootic is thickened where it adjoins the basioccipital lateral to the myodome. A conical excavation within this thickening of the prootic opens posteriorly to receive the anterior end of the sagitta (sacculith), the remainder of which lies in the saccular recess of the basioccipital.

The **exoccipitals** (EO, fig. 22, 26) are large and extensive bones, each consisting of: 1) a basal plate forming part of the floor of the posterior cranial cavity, 2) a large wing like lateral par-occipital process which not only forms the side wall of the cranial cavity but also forms the posterior boundary of the lateral semicircular canal, and 3) a small posterodorsal process enclosing the lateral occipital foramen. It forms a suture with the autopterotic anterolaterally, with the epiotic dorsally outside and laterally inside the subtemporal fossa, and with the prootic anteriorly both outside and inside the fossa. The exoccipital forms a suture mesially with the basioccipital, except at its hindmost end where the two bones interdigitate so closely as to appear fused. This is the only boundary between cartilage bones lacking intervening cartilage, and is restricted to the lateral surface of the proatlas vertebral centrum of the basioccipital. The posterodorsal extremity of the exoccipital is reduced to a strip of bone forming the margin of the enormous lateral occipital foramen (LOF, figs. 22, 24). Dorsally, this bony strip forms a short suture with the supraoccipital and mesially it is connected with its paired member of the opposite side by a median dorsal plate of cartilage, which forms the roof of the foramen magnum. Within the cranial cavity, each exoccipital has a horizontal plate which meets a corresponding plate from the other exoccipital in the midline. These plates form a platform (between the foramen magnum and cavum sinus imparis (CSI, fig. 23) which is the floor of the foramen magnum and the roof of the cavum sinus imparis. The basioccipital is thus excluded from the foramen magnum. A vertical ridge of bone descends from the under surface of these plates to form a small part of the lateral walls of the cavum sinus imparis; the remainder is formed by vertical plates ascending from the floor of the basioccipital to meet them. The glossopharyngeal foramen (IX) opens on the lateral surface of the exoccipital at its anteroventral corner. Behind this opening, below the bulge induced by the junction of the horizontal and posterior semicircular canals, and just in front of the oblique ridge between the lateral and the posterior surface of the bone, is the foramen for the vagus (X,fig. 25). The full size of this large foramen is apparent only in ventral view (X)

The **supraoccipital** (SOC, fig. 24) is shield-shaped, and forms the median posterior portion of the dorsal surface of the skull roofing the posterior cranial cavity . Its concave, anterior border conforms to the posterior chondrocranial fontanelle. The supraoccipital forms sutures laterally with the epiotics and exoccipitals. On either side, anterior to these sutures, it adjoins the cartilage plate first mentioned in connection with the autosphenotic; posterior to the sutures, it adjoins the cartilage roofing the foramen magnum. Medially, the bone rises as a high ridge which extends posteriorly as a thin plate-like process. This supraoccipital process rises above the highest level of the skull roof and is flanked by two prominent but low processes. Besides these two processes of the supraoccipital there are two outer processes which have sutures with the posterior processes from the occipitals to form lateral occipital foramina.

The **supratemporal** (ST,fig. 21, 24) covers the autopterotic and overlaps the hind edges of the autosphenotic thereby covering the suture between these two bones. It also overlaps the anterior edge of the epiotic, hiding much of the autopterotic-epiotic suture. It is bordered dorsoposteriorly by the lateral portion of extrascapular (fig. 21, 24). Its posteroventral corner is drawn out into a process for the articulation of the posttemporal bone (fig. 21, 24). It is traversed by the postorbital lateral-line canal, which it encloses in a bony tubule. A slit-like opening under the posterior edge of the supratemporal just above its posttemporal process leads into a slight, blind cavity between the supratemporal and the surfaces of the autopterotic and epiotic adjoining their common suture. Sagemehl (1891:553) termed this cavity the posterior temporal fossa and Regan (1911:26-28) calls it the supratemporal fossa. According to Regan, the posttemporal bone would be regarded as a posterior extension of the roof of the fossa. The fossa is best seen in posterior view, just lateroventral to the posttemporal spur of the epiotic and under the hind edge of the supratemporal bone.

The **parietals** (PA, fig. 21, 22, 24) are a pair of large rectangular dermal bones which lie over the hind part of the posterior chondrocranial fontanelle and the upper portion of the autosphenotics, supratemporals, epiotics, and supraoccipitals. The left parietal overlaps the right in the midline, and both are overlapped anteriorly by the frontals. They are smooth and slightly convex dorsally.

The **extrascapulars** are tabular bones consisting of three parts. The **medial extrascapular** (PP, fig. 21, 24) encloses the transverse commissural or supratemporal lateral line canal and runs along the upper surface and is fused to each parietal near its posterior margin; the **lateral extrascapular** (LS, fig. 21, 24) is free and extends along the posterior edge of the supratemporal bone above the dorsoanterior surface of the epiotic; the lateral extrascapular has a long vertical and a short horizontal limb. The lateral extrascpular encloses the construction of the postorbital, supratemporal, and posttemporal canals, transmit its enclosed laterosensory canal to a bony tubule fused to the posttemporal bone.

The **posttemporal** (PTT, fig. 21, 24) is a lancet-shaped bone, which lies over the epiotic just in front the ridge of the semicircular canal. It broadens out below, and rests on the posttemporal process of the supratemporal bone and upon the posttemporal process arising from the surface of the epiotic. The bony tubule fused to the posttemporal is the lateral extrascapular.

The **supracleithrum** (SCL, fig. 21, 24) is dagger-shaped in appearance and articulates with the outer surface of the dorsal end of the cleithrum. Externally, it is covered over and partly overlapped by the posterior edge of the opercular bone. At its dorsal end, the supracleithrum articulates with the undersurface of the posttemporal. For a short distance along the dorsoposterior edge a bony tube surmounts its lateral surface. The tube is fused to the supracleithrum and transmits the posttemporal canal from the posttemporal bone to the lateral-line scales.

The Basicranial Region

Cartilage bone: unpaired **basioccipital** (BO). Dermal bone: unpaired **parasphenoid (PS).** Otoliths: paired **lapillus, asteriscus,** and **sagitta.**

The **basioccipital** (BO, PPBO, MPBO, fig. 22–26) is a large pipe–shaped bone thickest in the middle. It is about twice as long as wide. The basioccipital connects with the prootics, exoccipitals, and the sagittae as mentioned above. It forms the roof and posterior wall of the myodome, the floor and side walls of the **cavum sinus imparis**, and of each **recessus sacculi**. Its ventral wall is continuous behind with the conical, posterior centrum – like occipital condyle which functions as a basioccipital centrum. Below and behind this is an open posteriorly directed **pharyngeal process** (PPBO, fig. 25, 26), serving as the origin for those muscles concerned with the retraction of the pharyngeal bones; the channel (dorsal view) itself serves to the dorsal aorta. On its ventral surface, the basioccipital bears a large oval **masticatory process** (MPBO, fig. 25) which is covered over during life by a horny pad opposing the teeth of the pharyngeal bones; behind the masticatory process, the pharyngeal process (ventral view) is produced into a prominent mid–ventral ridge. The anterior edge of the basioccipital forms a suture with the postmedial edges of the prootics, the medial arch forms a continuation of the myodome roof, and each lateral inverted arch forms the floor of a recessus sacculi. Dorsolaterally, on each side, the basioccipital forms a suture with the ventromedial edge of the exoccipital. Towards its posterior end, this suture yields to an interdigitation of the two bones so intimate as to appear fused, as mentioned above. This interdigitation occurs between the posteriorly produced hind end of the exoccipital and the lateral surface of the centrum of the occipital condyle. From the dorsal surface of the basioccipital floor, where it arches over the myodome, two thin plates ascend to meet opposing ventral ridges under the horizontal plates of the exoccipitals above. These plates of the basioccipital form not only the lateral walls of the cavum sinus imparis, as already mentioned, but each also forms the medial wall of the adjacent recessus sacculi. The position of the recessus sacculi is reflected externally by a ventrolaterally bulge involving the basioccipital and exoccipital and is termed the **bulla acustica lagenaris** (BAL, fig. 22, 25) by Sagemehl (1891:560). The bulla is the outer wall of the recess, which lodges two otoliths the asteriscus and sagitta (fig. 27).

The **paraphenoid** (PS, fig. 22, 23, 25, 26) is a very long cross-shaped bone which extends in the midline along the greater part of the ventral length of the neurocranium. At its anterior end it overlaps and is closely applied to the upper surface of the hind end of the prevomer. It is overlain dorsally by the posterior end of the ethmoid bone and the lateral ethmoids. From here to just in front of the otic region, it constitutes a thick, narrow strut of bone which skirts the lower edge of the vertical plate (interorbital septum) of the orbitosphenoid. As it approaches the prootics, it widens abruptly to its maximum width, becoming at the same time gradually thinner dorsoventrally. There is a median ventral vertical ridge running towards the anterior end. The parasphenoid finally tapers to a point, under the ventral surface of the basioccipital, and is firmly attached to the ventral surfaces of both prootics and basioccipital to form the floor of the posterior myodome. There is a notch opposite the facial foramen of each side, each notch forming with the adjacent surface of the prootic a **carotid foramen** (CA, fig. 25). In front of the carotid foramina, the parasphenoid also forms the side walls of the myodome, as the ventral lamellae of the prootics do not extend forward beyond these foramina. Just behind the level of the foramina, the pharyngobranchial bones (PB, fig. 23) are attached loosely to its ventral surface. On the dorsal surface of the bone, a vertical ridge runs from below the hind end of the orbitosphenoid to about the level of the carotid foramina. Toward its posterior end, this ridge is produced into a vertical partition resembling a tack (fig. 23). The ridge with its tack-like process partially divides the foremost portion of the posterior myodome into two corridors. The tack-shaped process is usually incompletely formed; it roofs part of the myodome so as to separate the optic foramen from the **hypophyseal foramen** (OF and HF, fig. 23, 26).

The **otoliths** are composed of crystralline calc spar (Moodie, 1922). There are three otoliths pres the **lapillus (utriculith)** lies in the recessus utriculi of the prootic, opposite the bulla acustica utricularis (BAU,fig. 22, 25), whereas the **asteriscus (lagenalith)** and **sagitta (saculith)** are both lodged in the recessus sacculi of the basiccipital, opposite the bulla acustica lagenaris (BAL, fig. 22, 25). The lapillus is slightly smaller but thicker than the asteriscus. It lies flat, with its greatest dimension in the transverse plane and its least dimension in the vertical plane. The disc-shaped asteriscus occupies the lateral portion of the recessus sacculi, where it stands on edge with its convex surface lateral and its plane surface medial, having the usual features of a cyprinid asteriscus. The long, slender and delicate sagitta lies mesial to the asteriscus in the same recess, its anterior end projecting from this recess in the bassioccipital into the excavation in the posterior edge of the prootic. It lies in the para-sagittal plane and almost horizontally, its anterior end slightly higher than its posterior end, having the usual plate-like expansion anteriorly and the needle-like extension posteriorly. The relationships of these three otoliths to the membranous labyrinth and its sensory maculae are figured for *Carassius* by Manning (1923).

Oromandibular Region

Cartilage bones:paired **autopalatines (P), metapterygoids (MPT), quadrates (Q), articulars (AR),** and **retroarticulars (RA)**; Dermal bones: paired **endopterygoids (ENT), ectopterogoids (ECT), premaxillaries (PM), maxillaries (MX), angulars (A),** and **dentaries(D).**

The **autopalatine** (P, fig. 22, 24, 25, 26) is an elongated rod-like bone, expanded at both ends but narrow in the middle. Its inner edge is more or less straight while the outer edge has a deep concavity. The ventral surface has a shallow groove, while the dorsal surface bears a short blunt process. Its posterior upper surface rests against the transverse ventral edge of the lateral ethmoid. It is movably articulated behind with the endopterygoid. The anterior half of the bone has a longitudinal ridge which terminates laterally in a maxillary process, at the anterior end which provides the insertion for the maxillary ligament. The mesial dorsal process contacts the cartilage-covered preethmoid.

The **metapterygoid** (MPT, figs. 22, 23) is a broad, flat plate, more or less quadrangular in outline. It overlaps the entopterygoid and ventrally overlaps the symplectic. The metapterygoid connects with the hyomandibular posteroventrally. The bone follows down along the outline of the parasphenoid and a ridge is produced along the lateral surface of the bone at the base of the slope.

The **quadrate** (Q, fig. 22, 23) is a flat and fan-shaped bone, which carries a ventral condylar process articulating with a notch in the angular. Close to the ventral border of the quadrate is a well-defined ridge directed obliquely backwards from the condyle, overlapping the anterior portion of the preopercular bone. On the inner surface close to the ventral border there is an elongated depression into which fits the anterior end of the symplectic. The dorsal portion of the quadrate partially covers the ectopterygoid.

The **ectopterygoid** (ECT, fig. 22, 23) is a somewhat triangular, thin bone which lies below the endopterygoid. Its anterior border is free and has a small notch. Along its ventral border, it overlaps the endopterygoid and metapterygoid. Externally, the bone is partially covered by the quadrate.

The **endopterygoid** (ENT, figs. 22, 23) is a large thin rhomboidal bone lying behind the autopalatine and dorsal to the ectopterygoid and metapterygoid. Its ventral surface is depressed while the external surface is convex and is partly covered by the metapterygoid. It is attached to the autopalatine along its anterior border; the inner border is free while the posterior border overlaps the metapterygoid and the outer border overlaps the ectopterygoid.

The **dentary** (D, fig. 27) is the largest bone in the mandible. It is hammer-shaped in most species; in *Osteochilus melanopleura, O. schlegeli,* and *O. kalabau* the dentary is a triangular scoop-shaped bone. The long axis of the hammer has a groove on its inner surface, into which fits the splint-like portion of the anguloarticular with the **coronomeckelian**. At its lower end, it fuses with the retroarticular. The anterodorsal (coronoid) process joins (by ligament) to the maxilla and premaxilla so that with the depression of the lower jaw the coronoid process of the dentary moves downward carrying with it the posterior end of maxillary. The anterior end of the dentary is expanded horizontally at the symphysis and this supports a thick keratinized callus sheath. In *Netropis* (Harrington, 1955) the ossified part of Meckel's cartilage, called the **mentomeckelian** is fused with the dentary; in *Osteochilus* I did not see it.

The **anguloarticular** consists of three fused bones. The main part is the **angular** (A, fig. 27) which is an elongated horizontal bone consisting of a thick proximal end and a thin splint-like anterior part. The thick end of the angular engulfs the **articular** (AR, fig. 27) which is a caudal part of Meckel's cartilage ossification. It is visible through the more lightly staining semi-tranparent dermal bone. The posterior end of the angular has an articulating facet for articulation with the quadrate. The angular extends anteriorly as a thin trough-like plate between the cylinder of Meckel's cartilage and a trough-like depression on the mesial surface of the dentary. The groove continues upwards into a narrow point of the mentomeckelian. At the depression on the mesial surface of the angular is the **coronomeckelian** (SA, fig. 27) which is shaped like half a machine bushing surmounted by a longitudinal vertical flange. The bushing-like part fits over the cylindrical unossified segment of Meckel's cartilage just above the exposed end of the articular.

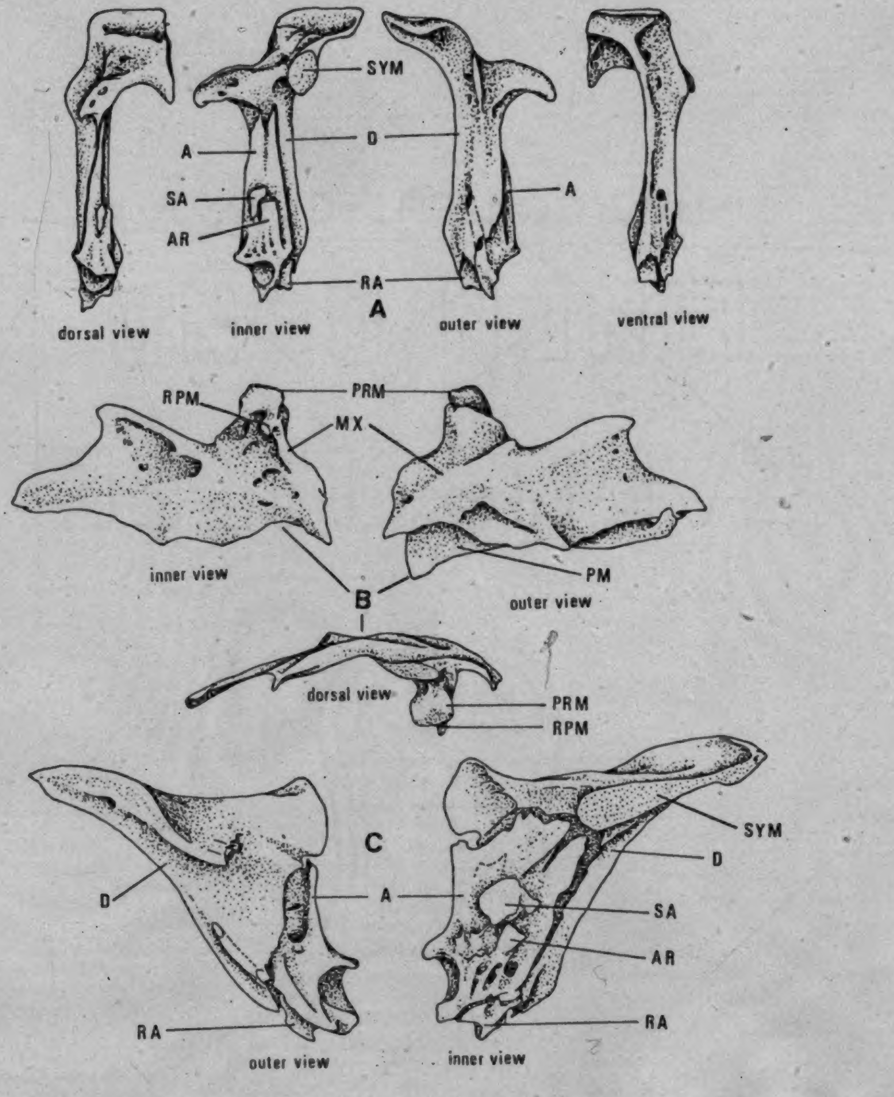

SYM
A
D
SA
AR
A
RA
A
dorsal view
inner view
outer view
ventral view
RPM
PRM
MX
inner view
B
PM
outer view
dorsal view
PRM
RPM
C
SYM
D
D
A
SA
AR
RA
RA
outer view
inner view

Figure 27 A. left side of the lower jaw of Osteochilus triporus

B. left side of the upper jaw of Osteochilus triporus

C. left side of the lower jaw of Osteochilus melanopleura

The **retroarticular** (RA, fig. 27) is the posterior most portion of the ossification of Meckel's cartilage (Harrington, 1955). It is a small, thick, irregular piece of bone that lies at the angle of the lower jaw and fits snugly into the ventral notch of the angular and the posterior end of the dentary. The posterior end of the retroarticular is connected by ligament to the anterior end of the interopercular bone.

The **maxillary** and the **premaxillary** (MX and PM, fig. 27). The maxillary is a thick curved bone of irregular shape lying dorsal to and parallel with the premaxilliary. It partially overlaps the premaxilliary and is produced anteriorly into two processes, one directed outwards and downwards and the other directed inwards and downwards; the former along with the lateral edge of the premaxillary is bound by means of connective tissue to the dorsal process of the dentary while the other process is bound to the anterior border of the autopalatine by a stout ligament. The inner surface of the bone is deeply concave and closely fits on the outer surface of the premaxillary. The anterior mesial edges of the two maxillaries do not meet in the middle line but are connected with each other by strong connective tissue. The median **rostral** (kinethmoid) bone (RO, fig. 23) of the ethmoidal region lies in a small space behind the symphysis of the maxillaries. Dorsolaterally, the maxillary overlaps with the lachrymal. The maxillaries, the premaxillaries, and the rostral are strongly bound together by fibrous tissue; these five elements thus form a compact structure which acts as one piece. The premaxillary curves mesiad anteriorly to form a symphysis with its other member. Posteriorly, it tapers and is slightly recurved and interlocked with the maxillary with a small hook. The anterior parts of the two premaxillaries are connected by the sigmoid ligament to the rostral bone and thence to the anterior part of the ethmoid. The premaxillaries are thus restricted in forward movement by the sigmoid ligament and in backward movement by the mesially directed rods of the maxillaries (at the dorsal process of the maxillary). Their lateral movement is restricted by the lower margins of the maxillaries which overlap them anteriorly and interlock by small hooks posteriorly.

Hyoid Region

Cartilage bones: paired, **hyomandibulars (HM), symplectics (SY), interhyals (IH), epihyals (EH), ceratohyals (CH), upper hypohyals (UH),** and **lower hypohyals (LH),** and unpaired **basihyal (BH).** Dermal bones: paired **opercles (OP), preopercles (POP), subopercles (SOP), interopercles (IOP),** and **branchiostegals (BS),** and unpaired **urohyal (URO).**

The **hyomandibular** (HM, fig. 28) is a strong elongated bone, which lies in an obliquely vertical position between the auditory capsule above and the preopercular below. It fits above into a facet contributed to by the pterosphenoid, autosphenotic, autopterotic, and prootic. It is found anteriorly with the metapterygoid, and below with the symplectic (with intervening cartilage). It has a thick strut with thin flanges extending on either side. The main strut subdivides above into three branches. The first two form the head which attaches to the neurocranial facet; the third forms the rounded condyle for the articular facet of the opercle (FO, fig. 28). On the mesial surface of the bone, at the confluence of the three branches with the main strut, there is a large foramen which leads into a canal running lengthwise within the main strut, and openning on the lower lateral surface of the bone by an oval foramen. The hyomandibular branch of the facial nerve enters the mesial foramen and emerges from the oval foramen (ROF, fig. 28 C.). It gives off the ramus opercularis superficials, which leaves the hyomandibular bone through a foramen beneath the opercular condyle, and enters another in the anterior edge of the opercular.

The **symplectic** (SY, figs. 21) is a long narrow bone lying in a horizontal position in front of the ventral corner of the hyomandibular; the anterior third of it fits into a groove on the dorsal surface of the posterior extension of the quadrate. The dorsal border of the posterior two-thirds of the symplectic is attached to the metapterygoid while the ventral border of the anterior half of the bone articulates with the interhyal. Externally, only a small portion of the symplectic is visible since it is largely overlaped by the preopercular bone.

The small, somewhat cylindrical **interhyal** (IH, fig. 22) is connected at one end with the cartilage between the hyomandibular, symplectic, and metapterygoid and at the other end with the cartilage extending to the upper end of the epihyal.

The **epihyal** (EH, fig. 28) is a thick, round, triangular bone. Its apex is directed dorsollaterally toward the interhyal, and its base is broadly articulated with the posterior end of the ceratohyal. Ventrally and slightly externally its anterior end is attached to the third or posteriormost branchiostegal ray.

The **ceratohyal** (CH, fig. 28) is a broad flat bone lying just in front of the epihyal. The mesial end terminates into two heads. The dorsal head articulates with the upper hypohyal, the ventral head, with the lower hypohyal. The first brachiostegal ray is attached internally while the second ray is attached externally along its ventral border.

The **upper hypohyal** (UH, figs. 28) is a curved subcylindrical rod articulating at one end with the ceratohyal and at the other with the lower hypohyal.

The **lower hypohyal** (LH, fig. 28) is a thick V-shaped bone, one limb of which articulates with the upper hypohyal, the other with the ceratohyal. Its medial surface joins in the midline that of its fellow of the opposite side.

The **basihyal** (BH, fig. 22) is a rather flattened, four sided bar, slightly deeper anteriorly. It extends toward the basibranchial and lies just above the junction of the two lower hypohyals at its posterior end. At the anterior end it projects free; the posterior end is closely attached to the dorsomedial surface of the upper hypohyals and to the anterior end of the basibranchial.

The **urohyal** (URH, fig. 28) is essentially a broad, flat, horizontal plate surmounted by a longitudinal, vertical plate. Anteriorly it becomes narrower, thicker, and rounder in contour, terminating in two lateral heads.

Each of the three flat, curved **branchiostegal rays** (BS, fig. 22, 28) is slightly produced anterodorsally where they articulates with the hyoid bar. The first two articulate with the ceratohyal internally and externally respectively, the third, with the epihyal externally.

The **preopercle** (POP, fig. 21) is a lunate-shaped bone, with the concave surface directed upwards and forwards. It overlies the lower posteriolateral surface of the hyomandibular, the hind end of the symplectic, the interhyal, the dorsolateral surface of interopercular, and the anterior edge of the opercle. The posterior process of the quadrate lies on top of the anterior part of the preopercular. The preopercular encloses the preopercular-mandibular laterosensory canal in a bony tube which varies a great deal between species in its shape and number of perforation.

The **interopercle** (IOP, fig. 21) is a long triangular bone which lies along the ventral border of the preopercle bone. It has a slightly concave upper edge. It overlaps with the lateral surface of the ceratohyal and the anterior end of the suboperculum. Its ventral edge is slightly curved, and forms the anterior half of the ventral edge of the gill cover and overlaps with the upper half of the posterior branchiostegal ray.

The **subopercle** (SOP, fig. 21) is a long saber-shaped bone. It has a slightly concave upper and a convex lower margin. Truncate anteriorly and with a sharp anterodorsal angle, it gradually narrows to a point behind. It is overlain anteriorly by the interopercle and dorsally by the lower edge of the opercular. The ventral border of the bone overlaps the hind part of the posterior branchiostegal rays. All bones of the opercle series are mesially concave and laterally convex.

The **opercle** (OP, figs. 28) is the largest and the most prominent and complex bone in the series. The bone is thin and shell-like except for two thick mesial struts, one along the anterior edge, the other diverging from the first ventroposteriorly, at the articular facet for the hyomandibular (FH, fig. 28) The thickened anterodorsal angle of the opercle (suprapreopercular process of Tretiakov, 1946; opercular arm of Nelson, 1949) is generally presumed to have evolved in connection with the insertion of the dialator operculi muscle

(Harrington, 1955). The anterior strut makes the entire leading edge of the bone rigid, and also serves for muscle insertion. On the internal edge of the strut just below the supraopercular process is the socket for the opercular knob of the hyomandibular, serving as a fulcrum for the dilation of the opercle. Just below the socket the anterior face of the strut is perforated by two foramina. These foramina receive the two branches of the ramus opercularis superficialis VII (ROF, fig. 28), which bifurcates upon its emergence from the foramen, in the hyomandibular beneath the knob. A single foramen may often receive both branches.

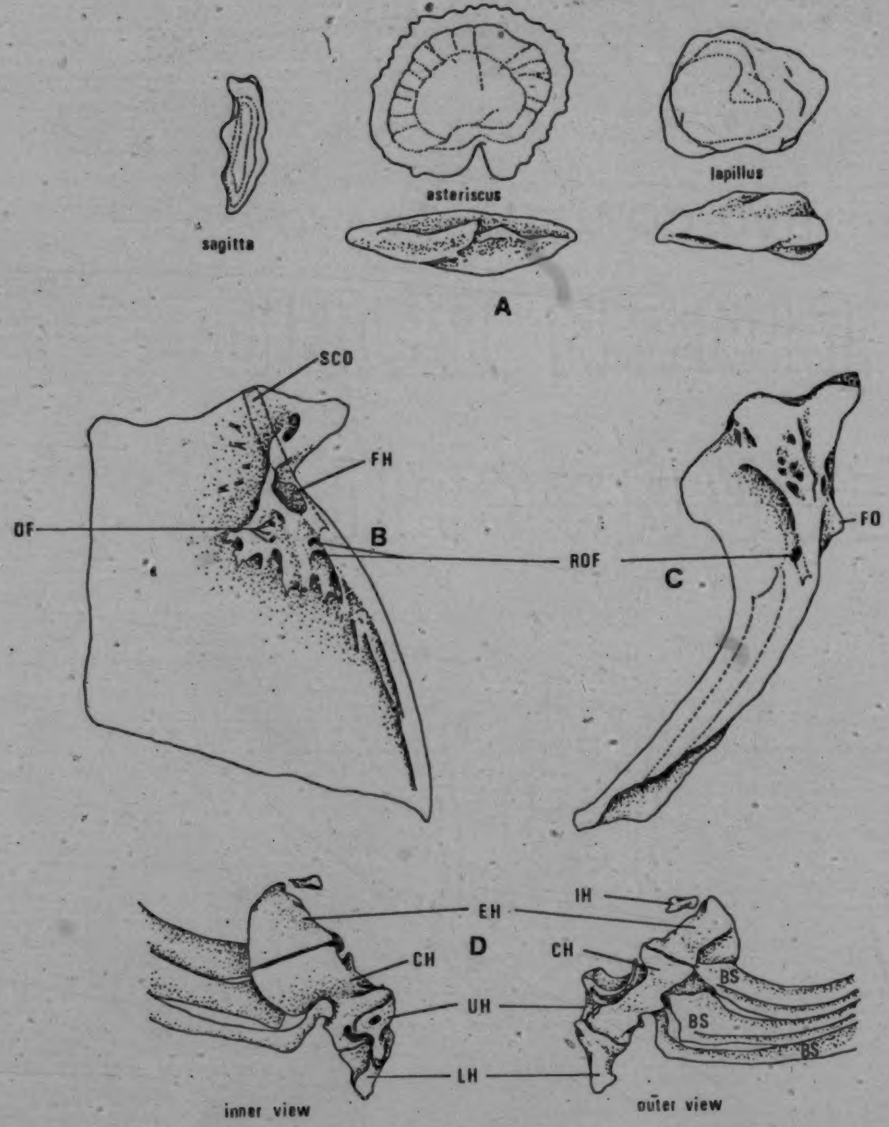

sagitta
asteriscus
lapillus
A
SCO
FH
OF
B
ROF
C
FO
IH
EH
D
CH
CH
BS
UH
BS
LH
BS
inner view
outer view

Figure 28 Osteochilus triporus, A. the otoliths, B. the inner view of opercular, C. the outer view of hyomandibular, D. left side of hyoid arch

The upper branch proceeds from its foramen through a canal piercing both struts just beneath the socket to open on the mesial surface of the opercle. This upper branch of the ramus then bifurcates, both parts giving off several small branches which pass from the mesial side of the opercle, through four to five foramina in the flat part of the bone (OF, fig. 28), to innerrate the sensory organs scattered over the lateral surface of the upper third of the bone. The lower branch of the ramus proceeds ventrad from its foramen, parallel with but a little back from the anterior edge of the bone. The course of the nerve is apparent to lateral view as it is enclosed by a superficial lamella of the opercle in a thin-walled bony tubelet similar to the tubular laterosensory canal bones. The nerve emerges from the lower end of this tubelet, midway between the articular socket and ventral border of the opercle, to supply sensory organs along the surface of the bone parallel with the anterior edge and ventral edge of opercular. At a point a little below the articular socket, there is an opening of the opercular-mandibular laterosensory canal (SCO, fig. 28 B) connected with the canal tube from the tip of the preopercle. This tube runs upward through the opercle bone and open at the upper edge of the opercle to join with the postorbital lateral line canal on the supratemporal bone.

Branchial Region

Cartilage bones: paired **pharyngobranchials (PB), epibranchials (EB), ceratobranchials (CB)**, and **hypobranchials (HB)**, and unpaired **basibranchial (BB)**. Ossified **gillrakers**.

The **pharyngobranchials (PB,** fig. 23) are small bony elements suspended beneath the posterior part of the parasphenoid and dorsal to the pharyngeal wall. Only three pairs of pharyngobranchials ossify in *Osteochilus;* these are followed behind by a pair of cartilage elements. The second and third pharyngobranchials are fused together. Ventrally, the pharyngobranchials are connected with the epibranchials.

The **epibranchials** (EB, fig. 23) are curved elongated bones grooved along their posterior surface; they lie at an oblique angle in a near vertical plane and are directed slightly backwards and outwards. They articulate dorsally with the pharyngobranchials and ventrally with the ceratobranchials. The fourth epibranchial has a caudally directed uncinate process. A fifth epibranchial is not evident, although Hubendick (1942) described a cartilaginous fifth epibranchial in *Leuciscus* rufilus (=*Rutilus rutilus*), which linked the pharyngeal bone and the cucullaris profundus muscle (trapezius muscle).

The **ceratobranchials** (CB, fig. 23) are long, thin, and trough-shaped bones similar to the epibranchials. They are the longest bone in the branchial series, forming the lateroventral part of the gill arches. There is a cartilaginous joint between the epibranchials and ceratobranchials.

The fifth pair of ceratobranchials is highly modified and is termed the **pharyngials** (PH, fig. 23). Each is more or less triangular in shape and lies in an oblique position immediately behind the fourth arch. The apex of the triangle is directed upwards and backwards and fits into the cup-like hollow of the subtemporal fossa, whereas the base is directed obliquely forwards and downwards. Of the remaining two sides of the triangle, one is directed posteroventrally and is convex in outline, while the other is directed anterodorsally and is highly concave. All three apices of the triangle are produced into strong processes, one of which is directed forwards, the second downwards, and the third upwards. The anterior process of each bone meets the corresponding process on the opposite side in the midline and is firmly bound to it by connective tissue. The outer surface of the triangle is highly fenestrated while the inner surface bears the large and strong pharyngeal teeth arranged in three rows. The first or innermost row comprises five teeth, the second row comprises four, while the third row comprises only two. These teeth work against the horny pad on the musticatory process of the basioccipital. The action of the pharyngeal bones and their teeth is controlled by several muscles from the postemporal fossa, the pharyngeal process of the bassioccipital, the dorsal part of the lower arm of cleithrum, and the third basi-and hypobranchial (a detailed study of the pharyngeal bone musculature is given in Eastman, 1971).

The **hypobranchials** (HB, fig. 23) are three pairs of comma-shaped bones. They lie vertically adjacent to the first, second, and third basibranchials. Hypobranchials are probably absent in all Ostariophysi.

The **basibranchials** (BB, fig. 23) are somewhat cylindrical in shape. In *Osteochilus* and *Labeo* the first basibranchial is missing; in *Osteochilus* the second basibranchial is shaped like a T, the arms of the T articulate with the first hypobranchial. The third basibranchial is similar in shape to the second but smaller and a little longer. The anterior part of the third basibranchial articulates with the posterior end of the second basibranchial; the second hypobranchial articulates with the second and third basibranchials between this joint. The posterior part of the third basibranchial articulates with the third pair of hypobranchials.

The epibranchials and ceratobranchials bear a double row of small processes, the **gill rakers**, which serve as a sieve to prevent the escape of food through the gill slits.

B. The Vertebral Column.

The vertebral column consists of 29 to 34 completely ossified amphicoelous vertebrae (including the Weberian apparatus and the last vertebra with the urostyle. It is divisible into (1) an anterior trunk region, in which the vertebrae bear movable ribs, and (2) a posterior caudal region, the vertebrae of which do not bear ribs but have haemal arches.

The centra of the vertebrae are well developed, and perforated by the notochordal canal. In adults the notochordal canal is closed. The surface of the centrum is provided with numerous strengthening ridges. The neural and haemal spines are directed obliquely backwards. The prezygapophyses of the precaudal region are more prominent than in the caudal region.

The Trunk region.

The trunk region consists of 16 vertebrae, all of which except the first four bear ribs on their parapophyses. The ribs on the last two (precaudal vertebra) are inmovable and much reduced in size.

The Weberian apparatus (WA, fig. 29, 30) consists of the first four trunk vertebrae which are highly modified and serve to connect the air bladder with the ear. These four vertebrae differ from the rest in the absence of parapophyses.

The first vertebra is connected with the skull and articulates with the outer edge of a deep conical depression at the posterior end of the basioccipital. It is a thin disc bearing a lateral process (LP1, fig. 30) from which a ligament extends to contact the medial face of the cleithrum.

The second and third centra are fused together and are represented by a single large centrum (the largest centrum in the entire vertebral column). Both its anterior and posterior surfaces are deeply concave. The anterior half of the centrum, representing the centrum of the second vertebra, bears a pair of transverse processes which are longer and stouter than those of the first vertebra and are situated immediately behind the latter. The third vertebra contains a lateral fossa for the articulation of the tripus. Extending dorsally from the second and third centra is the third neural plate (NP3). The dorsal border is triangular. On the anterior margin lies the second neural plate (NP2) which contacts the back of the skull. Lying below the anterolateral border of the second neural plate is the **claustrum** (CLA) which is a cartilaginous cup-shaped structure. A ligament runs from each claustrum to insert upon the basioccipital.

The fourth vertebra bears large stout lateral processes which are directed anteroventrally (fourth pleural ribs, PR4). The medial surface of each peural rib extends inwards as suspensorium (OSS, fig. 30), a thin plate curving anteriorly so that its tip underlies the posterior edge of the third vertebra, which forms a vertical wall. The anterior end of the air bladder rests firmly against this vertical wall. Dorsally, its neural arch and spine are long and well developed and abut against the third neural plate.

The **scaphium** (SCA, fig. 30) is heart-shaped and is capped dorsally by the claustrum. Ventrally, it rests above the first centrum and a ligament from a depression on its posterior face connects this bone with the intercalarium.

The **intercalarium** (INC, fig. 30) is a very small bony nodule with a short inwardly directed spine-like process. It stretches between the scaphium and the anterior end of the tripus. A ligament (a continuation of the one extended from the scaphium) attaches ventrally and inserts upon the leading edge of the tripus.

The **tripus** (TR, fig. 30) is a flat triangular plate articulating with the third vertebra. Anteriorly, it contacts the lateral process of the second vertebra (LP2); posteriorly, its tip connects with the medial face of the process emanating from the fourth plural rib (PR4).

There are 12 *trunk vertebrae* (excluding the Weberian apparatus)> (fig. 29, 31). A typical trunk vertebra (fifth to 16th) consists of a short, deeply biconcave centrum. A large median depression is present on the dorsal surface of the body of the vertebra reaching almost to the centre of the vertebra. A similar median depression lies on the ventral surface while laterally there are two depressions, one dorsolateral and one ventrolateral separated by a median ridge. The **neurapophyses** extend from the anterolateral borders of the median dorsal depressions. These processes are directed obliquely backwards, uniting dorsally to form the **neural arch**. The posteriorly directed **neural spine**, arising dorsally from the neural arch, is long, thin, and pointed. The **prezygopophyses** are small blunt processes arising anteriorly from the thickened and broadened bases of the neurapophyses. These processes articulate with a corresponding pair of processes, the **postzygapophyses**, projecting from the posterolateral edges of the vertebrae. The prezygapophyses and postzygapophyses of two adjecent vertebrae enclose a pair of small foramina, one on each side for a spinal nerve. A pair of short **parapophyses** arises from the ventrolateral surfaces of the centrum. A rib is attached to each parapophysis by a ligament. The parapophyses of the anterior vertebrae (fifth to 14th only) are distinct and separate.

Pre-caudal region (fig. 29, 31)

The 16th vertebrae differ from the other trunk vertebrae in that the parapophyses are firmly fused with the anterior edges of the ventrolateral depressions and pass outwards, downwards, and slightly backwards. These posterior vertebrae also bear at their posterolateral ends a small spine-like process directed downwards and backwards, the posteroventral processes.

Caudal region

The caudal region consists of 15 to 17 vertebrae. A typical caudal vertebra, like a trunk vertebra, consists of a short biconcave centrum with a median dorsal depression, a median ventral depression, and two lateral depressions on each side. The neural arch arises from the anterolateral border of the median dorsal depression and is produced above into a long posteriorly directed neural spine. The prezygapophyses and postzygapophyses are present in the same position as in the typical trunk vertebra. From the anterolateral border of the medioventral depression arises a pair of **haemapophyses** directed obliquely backwards. These haemapophyses pass downwards and meet in the midvetral line forming the **haemal arch** and enclosing the **haemal canal**, through which run the caudal artery and vein. Each haemal arch is produced into a backwardly directed haemal spine. The bases of the haemapophyses are thickened and broadened. A pair of small blunt posterolateral processes arises from the posterior border of the bases of the centra and corresponds to the similar processes present in the trunk vertebrae. The vertebrae of the caudal region can be divided into three types based on the differences in the haemal canal and spine.

The first vertebra of the caudal region (17th vetrebra, fig. 29) differs from the rest in having two haemal spines instead of one; the haemapophyses after fusing together, diverge laterally to form two spines. This vertebra also differs in having a large circular haemal canal.

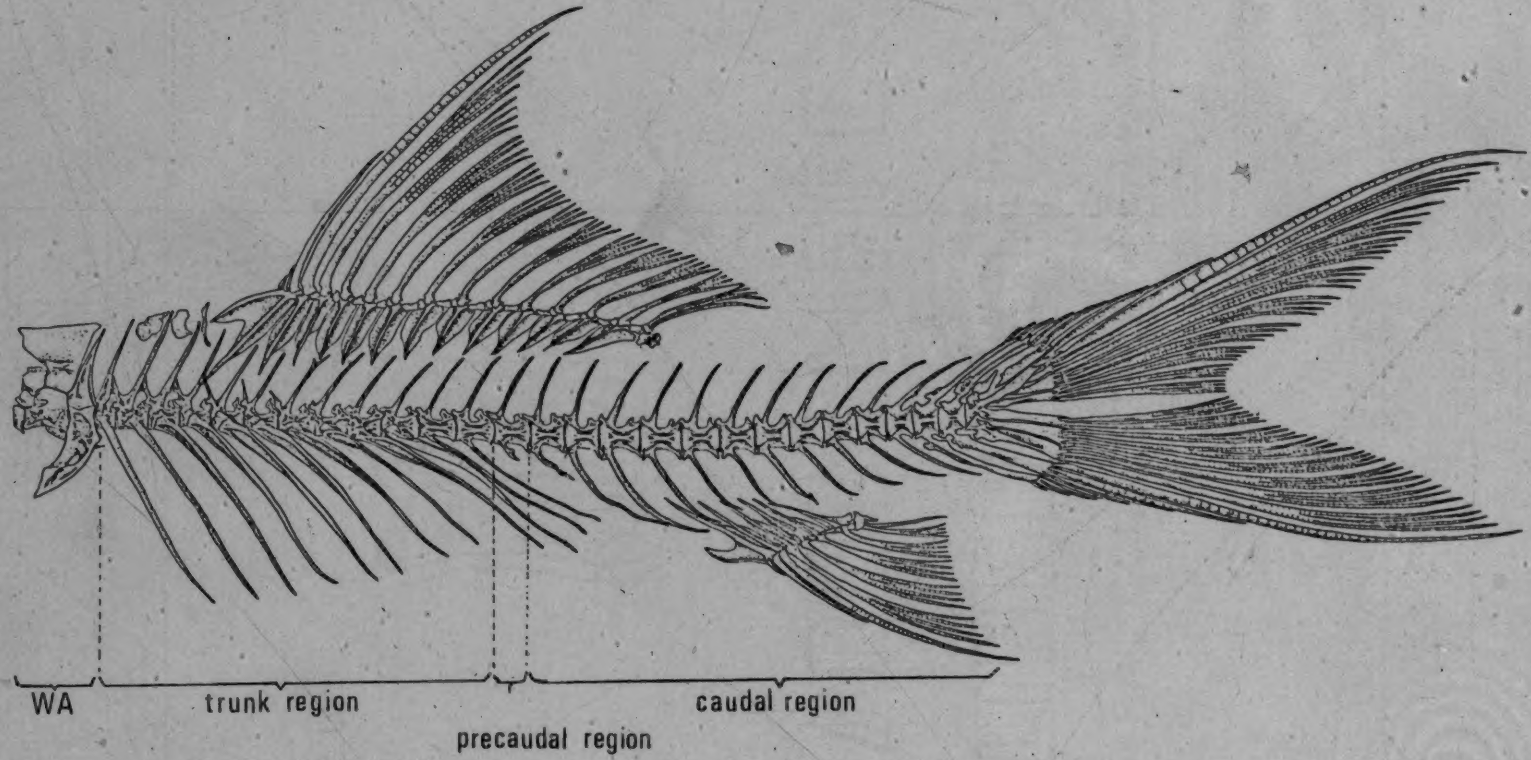
The remaining caudal vertebrae except for the last three are typical in having a single posteriorly directed spine and a triangular haemal canal.

The last three vertebrae are specially modified for the support of the caudal fin. The last caudal vertebra is produced posteriorly into an upturned rod-like **urostyle**. The urostyle is a solid structure with a groove on its ventral surface into which fit the proximal ends of four flat bony rods – the hypurals 3-6 (see page... , under caudal fin). The first two preural vertebrae are modified only to the extent that their neural and haemal spines are flattened and supportting about five to six unbranched upper and lower procurrent caudal fin rays.

The median fins

The skeleton of the median fins consists of two sets of structures: (1) a series of parallel bony rods called the **endoskeletal radials** or **pterygiophores** or **somactidia**, and (2) the **dermal fin-rays** or **dermotrichia**. Each radial typically consists of three segments, a **proximal**, a **mesial**, and a **distal** element (fig. 31). The dermotrichia support the free fold of the fin and are disposed on both of its sides, giving attachment to the radial muscles.

In *Osteochilus* the dermotrichia (lepidotrichia), or fin rays are jointed and branched and have a bony texture.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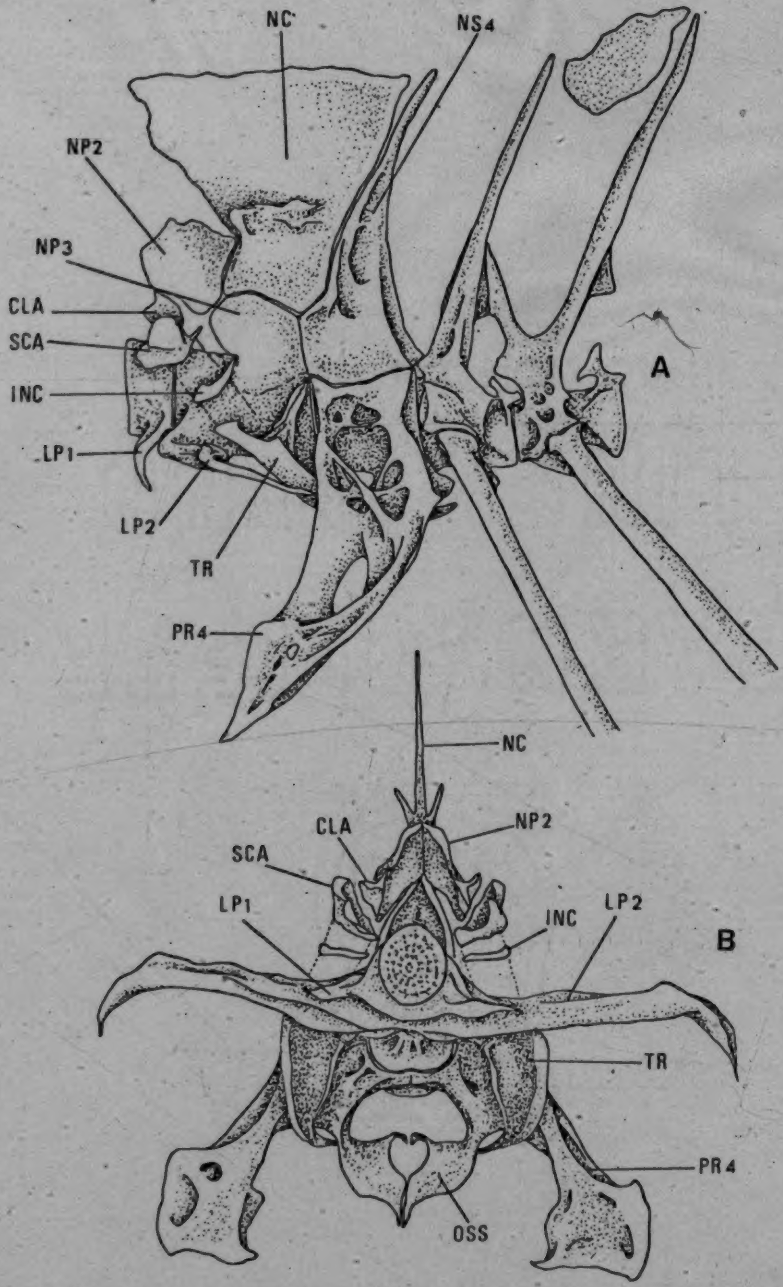
trunk region
precaudal region
caudal region

Fig. 29 Osteochilus triporus, axial skeleton (without skull)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TR
PR4
OSS

figure 30 *Osteochilus* *triporus*, the Weberian apparatus, A. lateral view, B. anterior view

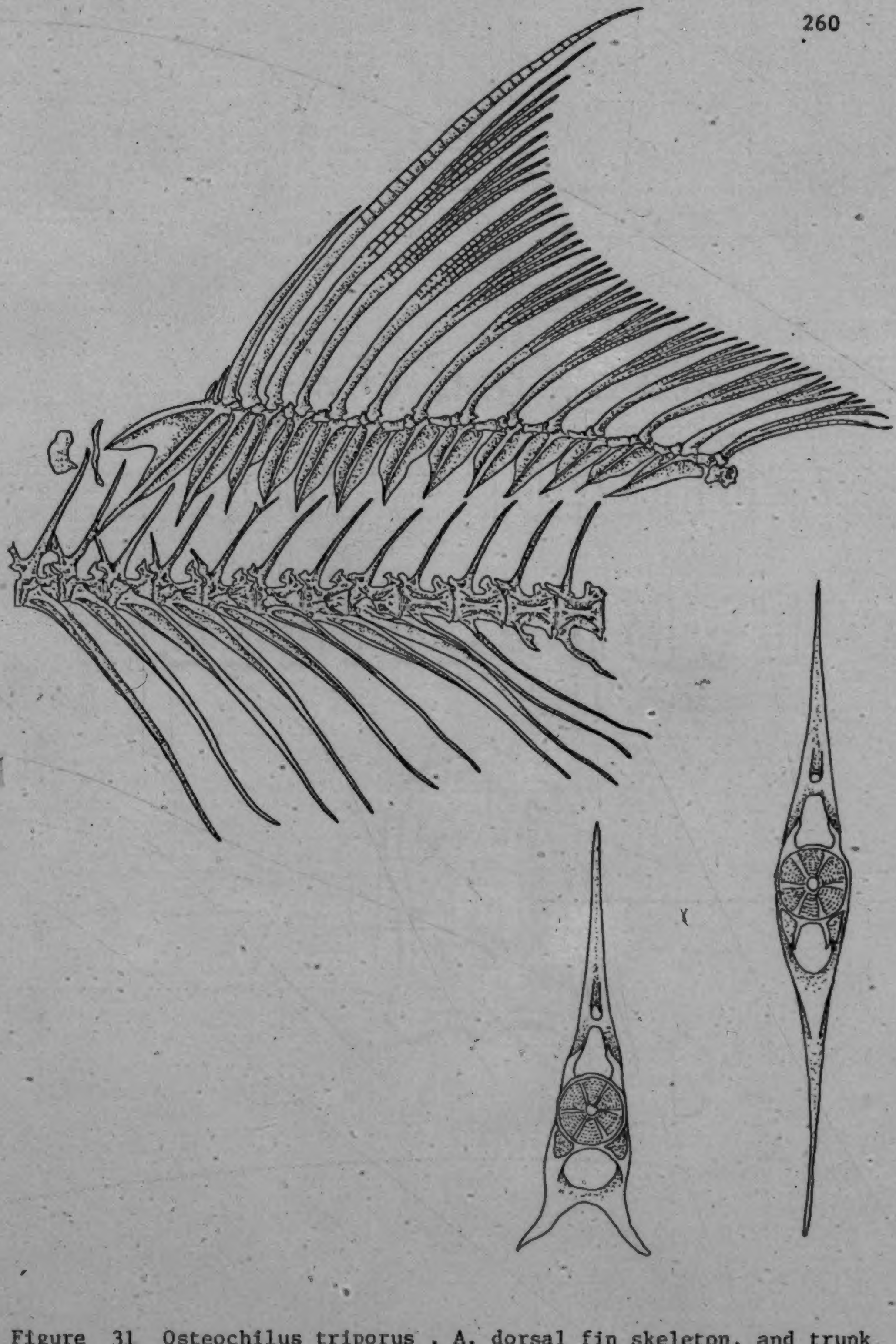
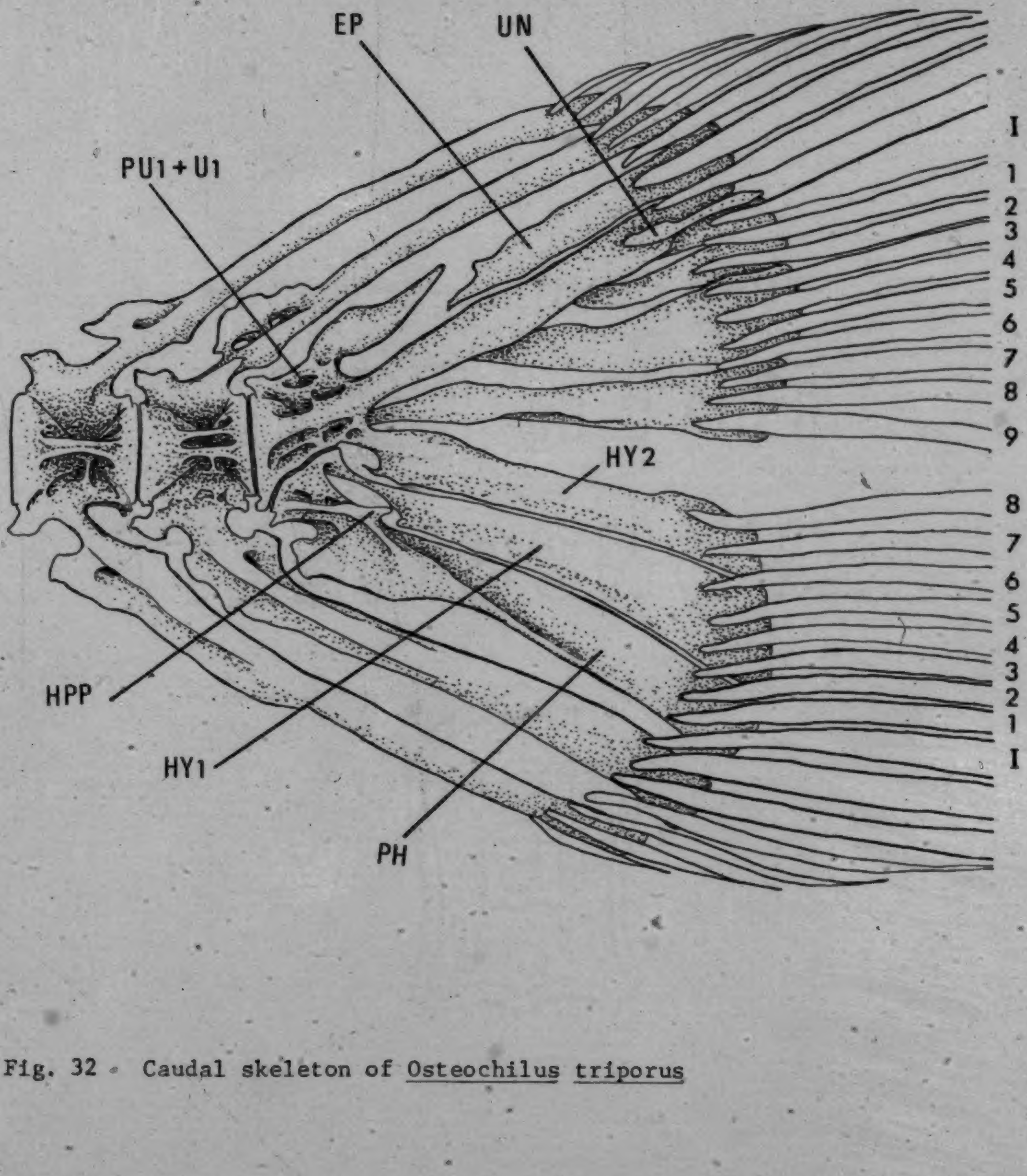


Figure 31 *Osteochilus triporus* , A. dorsal fin skeleton, and trunk vetebrae, B. anterior view of precaudal vetebra, C. anterior view of caudal vertebra


EP
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PU1+U1
I
1
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HY2
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2
1
I
HPP
HY1
PH

Fig. 32 . Caudal skeleton of Osteochilus triporus

1 The dorsal fin(fig. 31)

The dorsal fin is supported by 14 - 22 fin rays associated with 12-20 radials. The proximal segment is large and dragger-shaped and is sometimes called the interspinous bone or the axonost; the mesial segment is short, while the distal piece is still further reduced in size, being represented only by a double bony nodule. The last radial is reduced and is represented by the proximal segment only. The first interspinous bone lies between the neural spines of the eighth and ninth vertebrae. The proximal end of each interspinous bone is narrow, more or less pointed, and lies between two neural spines; the distal portion is broad and thickened and has four longitudinal ridges, an anterior and a posterior and two laterals, which meet along the axis of the bone.

The mesial segment of each radial lies obliquely between its proximal segment and the fin ray that articulates on the succeeding radial. At its distal end, the mesial segment carries the distal double bony nodule which thus comes to lie in connection not with its own fin ray but with the succeeding fin ray (fig. 31). The distal segment of the radial thus lies between the proximal ends of two adjacent fin rays and articulates with the posterior ray.

The first four fin rays are unbranched and are spine-like in appearance, increasing in size from the front posteriorly while the remaining rays are branched. At their proximal ends the lepidotrichia diverge slightly and enclose the distal sigment of the preceeding radial to which they are firmly attached by ligaments.

The anal fin (fig. 29)

The anal fin consists of eight fin rays, supported by seven radials. Of the seven radials, the first six are well developed, while the seventh is small. The structure of the radials and the fin rays and their articulations are very similar to those of the dorsal fin. The first interspinous bone usually lies inbetween the haemal spine of the 21st and 22nd vertebrae, while the sixth lies between the haemal spine of the 23rd and 24th vertebrae. The first three fin rays are unbranched while the rest are branched.

The caudal fin (fig. 32)

The caudal fin is a large vertically expanded structure, supported by a number of flattened bony rods which lie on both the dorsal and ventral sides of the urostyle. These rods consist of a single free epural which lies just above the urostyle, a single pair of free uroneurals at the tip of urostyle, and six hypurals, which lie on the ventral side of the urostyle. The parhypural and first hypural are fused at the base with a ball and socket articulation to the urocentrum. The rest of the hypurals attach to the urocentrum or urostyle. The third to sixth hypurals form the upper lobe of the caudal peduncle, while the first two and the parhypural form the lower lobe of the caudal peduncle. A well developed hypurapophysis is on the base of the parhypural. The principle caudal rays are I,9+8,I (as in all cyprinidae).

THE APPENDICULAR SKELETON

The pectoral and pelvic girdles together with their fins constitute the appendicular skeleton. The pectoral girdle lies immediately behind and beneath the last branchial arch, while the pelvic girdle lies in the abdominal region, a short distance in front of the anal fin.

A. The Pectoral Girdle

The pectoral girdle (fig. 33) consists of cartilage bones and dermal bones. The paired cartilage bones consist of: a scapula, a coracoid, and a mesocoracoid. The dermal bones consist on each side of a large cleithrum, a supracleithrum, and a postcleithrum.

The **cleithrum** (CL) is the largest and the most prominent bone. It is crescent-shaped and consists of two distinct portions: a triangular, posterior, vertical portion and a large, anterior, obliquely horizontal portion, the two portions being separated from each other by a crescentic ridge. The obliquely horizontal portion forms the ventral and posterior boundary of the branchial chamber; when the branchial chamber is closed, the posterior edge of the operculum fits against the cresentic ridge separating the two portions of the cleithrum. The anteroventral end of the bone extends forward beneath the gill chamber and unites firmly to the corresponding part of its fellow of the opposite side in the median line. The inner margin of the horizontal portion is produced into a broad and truncated flat process which is bound by means of connective tissue to the corresponding process of the other side. Just behind and above this process lies the fifth branchial arch. The dorsal surface of the cleithrum gives attachment to the anterior (first) muscle of the inferior pharyngeal bone. The surface of the cleithrum has two high ridges, an anterior one to which the anterior end of the coracoid is attached and a posterior one running obliquely inwards and backwards, to which the coracoid and the scapula are attached on its posterior edge. The dorsoposterior portion of the cleithrum has a deep hollow on its inner surface in which muscles attach.

The **postcleithrum** is a slender rod-like bone embeded in muscles. It is connected by ligament to the inner surface of the posterior end of the vertical portion of the cleithrum and passes inwards and downwards across the base of the pectoral fin.

The **supracleithrum** (SCL, fig. 21) is a dagger-shaped elongated bone lying over the outer surface of the dorsal end of the cleithrum. Externally, it is partly overlapped by the posterior edge of the opercular bone. At its dorsal end, the supracleithrum articulates with a small conical bone - the posttemporal. The posttemporal fits into a groove on the dorsal surface of the pterotic and articulates anteriorly with the extrascapular and the supratemporal bone.

The **coracoid** (COR) is a large fenestrated bone, irregularly triangular, lying in an obliquely vertical position internal to the scapula and ventral to the mesocoracoid. The anterior ends of the two coracoids converge toward the mid-ventral line and articulate with a ridge borne on the anteromedian processes of the cleithra, leaving a large elongated fissure on each side between the coracoid and the cleithrum. The posterior end of each coracoid articulates laterally with the scapula, dorsally with the mesocoracoid, and posteriorly with the mesial outgrowth of the scapula and the second and third radials. The inner margin of the posterior third of the coracoid is sutured with the inner margin of a horizontal ridge given off from the inner surface of the cleithrum.

The **mesocoracoid** (MC) is an inverted Y-shaped bone attached to the inner surface of the cleithrum; the inner limb of the Y articulates ventrally with the coracoid and with the mesial outgrowth of the scapula; the outer limb and the main shank of the Y are closely applied to the inner surface of the cleithrum, the outer limb also articulating ventrally with the external or the lateral scapular outgrowth.

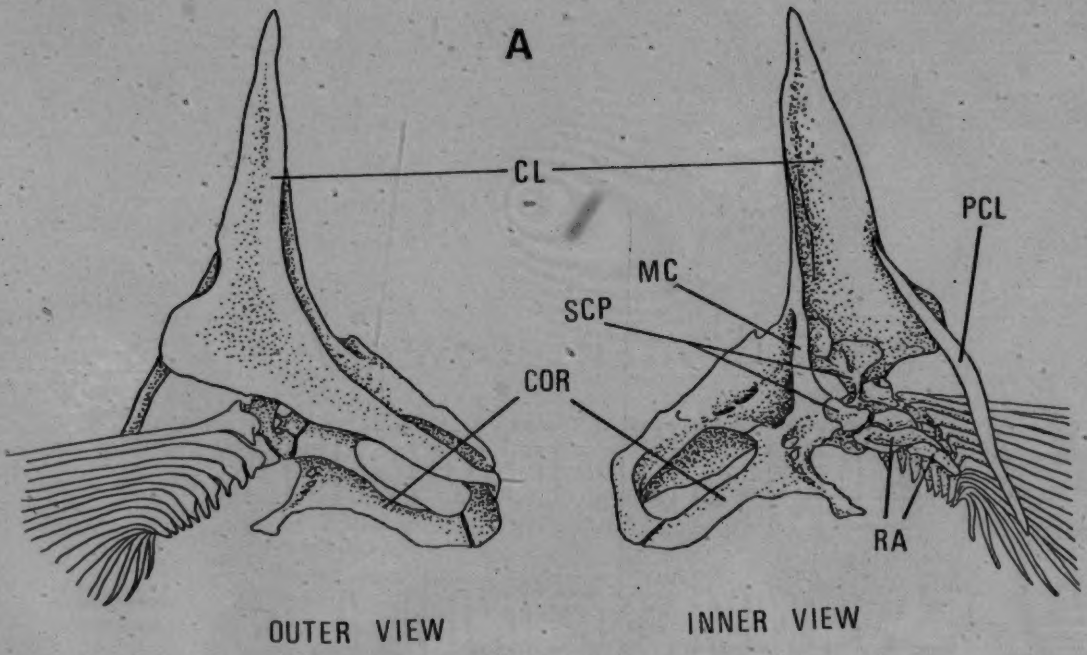
The **scapula** (SCP) is a ring-shaped bone lying laterally on the inner surface of the cleithrum; it has two flattened outgrowths - one lateral and one mesial. The lateral outgrowth is closely applied to the inner surface of the cleithrum, whereas the mesial outgrowth articulates internally with the mesocoracoid and the coracoid and posteriorly with the first and second radials. The **dorsal erector muscle** inserts into an opening of the scapular region which is closed dorsally by a mesocoracoid. The branchial artery and the branchial nerve pass through a large foramen of the ring of the so-called scapular foramen.

The skeleton of the pectoral fin, like that of the median fins, consists of two sets of structures: the radials and the dermal fin rays (lepidotrichia). The pectoral fin is supported by 13 to 16 rays which attach to four radials. The radials are joined to the scapula and the coracoid. The first or preaxial radial is a stout bony piece which is attached to the posterior end of the scapula. The second radial, which is slightly larger, attaches to the ventral edge of the scapula. The third radial is the largest of the series and is connected to the posterior end of coracoid. The fourth or postaxial radial abuts against the ventral edge of the third radial. The fin rays which support the triangular pectoral fin are long, slender, jointed rods having essentially the same characters as those of unpaired fins. The first or preaxial ray is the largest and is unbranched. The two lepidotrichs of which the first ray is composed can be easily distinguished: one of them articulates directly with the scapula and the other with the first radial. The other fin rays attach to the four radials.

B. The Pelvic Girdle.

The pelvic girdle (fig. 33) has fewer elements than the pectoral girdle. It consists only of the paired endochondral **pelvic bones** which lie in the ventral abdominal wall and a small cartilaginous rod at the hind end of the original cartilage which remains unossified and is attached to the posterior end of the pelvic bones. Each pelvic bone consists of two parts: an anterior elongate portion which bears a prominent deep groove on its ventral surface and is forked in front, and a posterior stout rod-like process which continues backward into a narrow elongate piece of cartilage. The posterior process lies along the inner border of the pelvic fin and is connected with its fellow of the opposite side in the midline.

The pelvic fin is supported by nine fin rays which are attached proximally to three small radials. The radials are connected to the posterior border of the pelvic bone. The first or outer radial is a double piece which is relatively triangular in shape. The second or the middle radial which is slightly bigger is again a double piece, quadrangular in shape. The third radial is the largest of the series and is represented by a single slightly curved piece thickened at its proximal end. The nine fin rays which support the triangular pelvic fin are long, slender, jointed rods having essentially the same characters as those of pectoral fin. The first or preaxial ray is the largest and is jointed but unbranched; the remaining eight are jointed and branched. Of the nine fin rays the first two attach to each of the smaller radials while the other five attach to the third radial.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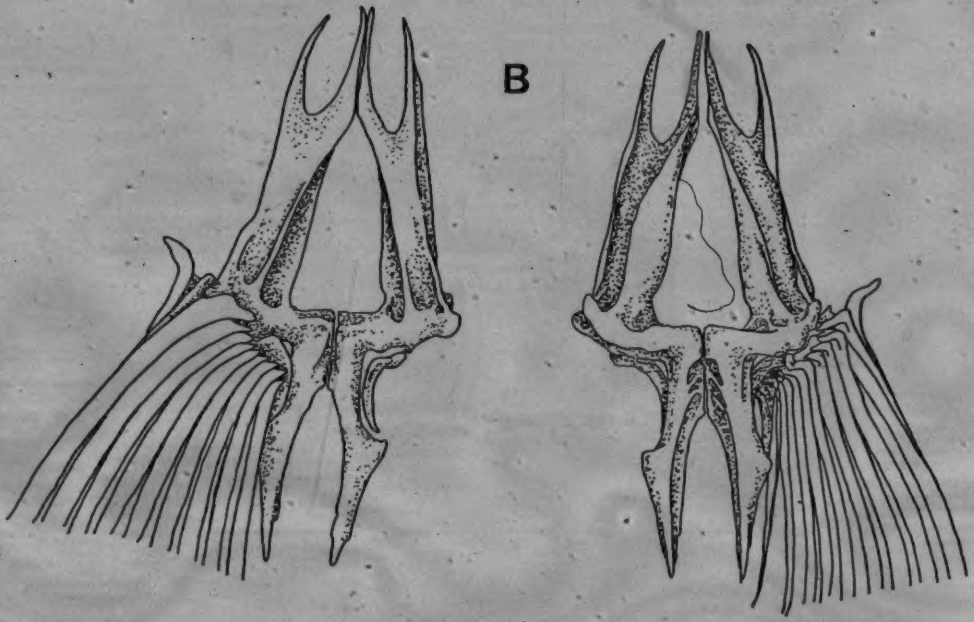


Figure 33 Osteochilus triporus , A. pectoral girdle, B. pelvic girdle

INTERRELATIONSHIPS OF LABEINAE

SYSTEMATIC PLACEMENT OF *OSTEOCHILUS*

The systematic placement of *Osteochilus* is as follows:

Order Cypriniformes
  Suborder Cyprinoidei
    Family Cyprinidae

About 10 subfamilies are currently recognized in the family Cyprinidae. Smith (1945) placed *Osteochilus* in the subfamilyCyprininae and recognized the genera *Garra, Crossocheilus, Epalzeorhynchos*, and *Mekongina* in the subfamily Garrinae. Nikolsky (1954) did not recognize Garrinae and divided Cyprininae into Cyprininae and Barbinae. In his classification, Barbinae is the largest subfamily of Cyprinidae and Cyprininae contains only two genera (*Cyprinus* and *Carassius*). Reid (1978) proposed a new subfamily Labeinae (by subdividing Barbinae). This new subfamily contains 12 genera (10 in Reid) and also includes *Osteochilus* and the subfamily Garrinae of Smith (1945). Reid (1978) recognized three tribes in Labeinae as follows:

1. Tylognathini	2 genera	*Tylognathus* *Barbichthys*
2. Labeini	5 genera (4 in Reid)	*Cirrhinus* *Lobiobarbus* *Lobochilus* (not by Reid) *Osteochilus* *Labeo*
3. Garrini	5 genera (4 in Reid)	*Crossocheilus* *Epalzeorhynchos*

Mekongina (not by Reid)
Garra
Semilabeo

Characters used to separate Labeinae from Barbinae are as follows:

1. The downgrowth of a rostal fold covering part of upper lip
2. Hypertrophy of upper lip (upper labial fold) and lower lip (lower labial fold).
3. The occurrence of the precoronoid arm of the lower jaw bone.
4. Presence of lower labial fold.
5. Presence of vomero-palatine organ on the roof of the buccopharynx.
6. The occurrence of the terete process of the basioccipital bone.
7. Having the neural complex in direct contact with the supraoccipital region of the skull.

The detailed study of these organs will be discussed in the next section.

Results of my studies in the next sections (osteology and oromandibular soft part anatomy) favor the removal of *Cirrhinus* and *Labiobarbus* from the tribe Labeini, and their inclusion in the primitive tribe Tylognathini.

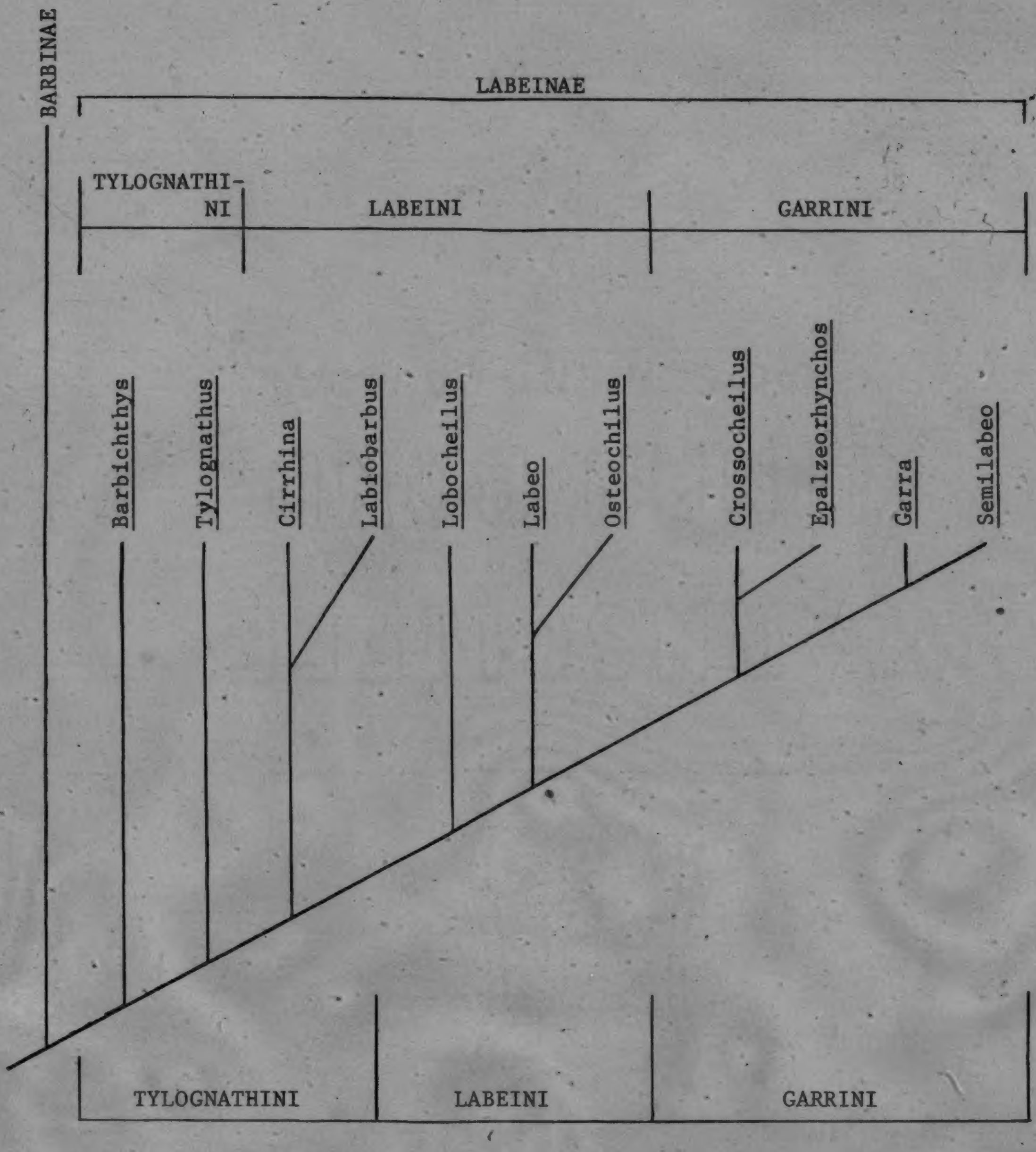

BARBINAE
LABEINAE
TYLOGNATHI-NI
LABEINI
GARRINI
Barbichthys
Tylognathus
Cirrhina
Labiobarbus
Lobocheilus
Labeo
Osteochilus
Crossocheilus
Epalzeorhynchos
Garra
Semilabeo
TYLOGNATHINI
LABEINI
GARRINI

Fig. 34 Reid's cladogram of the subfamily Labeinae
The bottom part is my subdivision into tribes

OSTEOLOGICAL ANALYSIS

In order to determine the relationships of *Osteochilus* and of other labeine genera I have conducted an osteological study and comparison of the various species of Labeinae. Because of the limitation of specimens for these studies I have studied only one species for most genera except that three species of *Labeo* and 17 species of *Osteochilus* were utilized.

There are only a few published osteological studies of labeine cyprinids. The following is a list of the publications available: Sarbahi, 1932 Girgis, 1952a; Ramaswami, 1955; Saxena, 1966; Greenwood and Jubb, 1967; and Howes, 1978.

The osteology of many genera used in this study has not been published before including: *Barbichthys, Tylognathus, Labiobarbus, Osteochilus, Lobocheilus,* and *Crossocheilus*. The comparisons described here were done only for those regions of the osteocranium which show interesting modifications among species and genera.

List of the Species Used in the Osteological Studies

Barbichthys laevis
Tylognathus behri
Cirrhinus macrosemion
Cirrhinus chinensis
Labiobarbus lineatus
Lobocheilus quadrilineatus
Labeo chrysophekadion
Labeo rohita
Labeo dyocheilus
Osteochilus macrocephalus
Osteochilus lini
Osteochilus salburyi

Osteochilus kahajanensis chini

Osteochilus pleurotaenia

Osteochilus waandersi

Osteochilus ingeri

Osteochilus spirulus

Osteochilus triporus

Osteochilus intermedius

Osteochilus sarawakensis

Osteochilus hasselti

Osteochilus kappeni

Osteochilus borneensis

Osteochilus schlegeli

Osteochilus melanopleura

Crossocheilus reticulatus

Garra fuliginosa

Ethmoid Region

The **supraethmoid** is variously developed in cyprinids. In the Labeinae the narrow ethmoid with a deep medial notch is considered to be the more generalized condition. From outgroup comparison, the small ethmoid state is considered to be primitive. In *Barbichthys*, the median notch is deep and greatly extended anteriorly, while the anterolateral corner is rounded. In *Tylognathus* and *Cirrhinus*, the supraethmoid is short and narrow and the anterolateral corner is produced but not pointed. In *Labeo* the ethmoid is variously developed; according to Howes(1978) *Labeo* can have a short or a long ethmoid (the short ethmoid condition is usually has a broader supraethmoid). In my examination of three species of *Labeo*, *L. chrysophekadion* and *L. rohita* have a relatively short and broad supraethmoid, but *L. dyocheilus* has a narrow and small supraethmoid. Similar to *Labeo*, *Osteochilus* has a variously developed supraethmoid. The anterolateral corner of the bone is produced into a pointed process which is unique in this genus. In the derived form of *Osteochilus (the O. hasselti* and *O. melanopleura* group), the supraethmoid is short and greatly expanded laterally, almost as wide as the skull. In Garrini (*Crossocheilus* and *Garra*), the supraethmoid is narrow and small (the primitive condition).

In most Labeinae and Barbeinae the anterior process of the **lateral ethmoid** is poorly developed. This process is well developed in *Labeo* and *Osteochilus*. It is usually strong and curved inward in *Labeo*, but flat and laminated in most *Osteochilus* except in *O. pleurotaenia* and *O. triporus*

Ramaswami (1955) notes the presence of a facet on the ventral part of the lateral ethmoid which articulates with the endopterygoid in *Labeo macrostoma* and *Cyprinus carpio*. Howes (1978) examined many species of *Labeo* and found that they have this facet variously developed and it seems to be well developed in those species with a long ethmoid but is virtually absent in those with a short ethmoid. In the three species of *Labeo* I have examined this facet is well developed in species regardless of whether or not there is a long or a short ethmoid. This facet is slightly developed in *Barbichthys*, but well developed in *Tylognathus*, *Cirrhinus*, and *Labiobarbus*, and missing in *Lobocheilus*, *Osteochilus*, and in Garrini.

Oromandibular Region

The **palatine** varies little between genera of Labeinae. Differences involve the degree of development of the articular head with the preethmoid. In most genera of Labeinae the dorso-mesial process of the autopalatine is long and slender and protudes laterally into the channel between the supraethmoid and the preethmoid. In the three species of *Labeo* examined, there are various degrees of development of this process. In all *Osteochilus* the process is reduced to a blunt wing just covering the head of the preethmoid.

The Upper jaw

The genera of Labeinae examined show a high degree of modification in the shape of the **maxillary** and in the articulating point between the maxillary and **premaxillary** at their posterior end.

In *Barbichthys* (fig. 35), the rostral process of the maxillary is long and vertically directed. The prevomerine process is blunt and curved; the posterodorsal process is well developed. A large foramen for the nerve supplying the rostral barbel (subdivision of the superior maxillary ramus of the trigiminal nerve) is present at the anterior lower part. The posteroventral process of the maxillary curves inward and hooks over the posterior tip of the premaxillary.

In *Tylognathus* (fig. 35), the overall characters are similar to those of *Barbichthys*, except that the anterodorsal process is protruded. The nerve foramen of the rostral barbel is small, but there are numerous small openings at the anterior end of the maxillary, probably for the nerve fibres supplying the numerous tubercles on the snout. The joint between the posterior part of maxillary and premaxillary is similar to that of *Barbichthys*.

In *Cirrihinus* and *Labiobarbus* (fig. 35), the maxillary is quite small compared to the body length. The overall characters are also similar to *Tylognathus*, but the anterior part is reduced to almost being truncated, the anterodorsal process rudimentary. There is a large foramen just anterior to the mid-portion of the maxillary for the nerve supplying the rostral barbel, and a few smaller ones of unknown function. The hook at the posterior end of the maxillary is more developed than in the first two genera.

In *Lobocheilus* (fig. 36), the anterior part of the maxillary is highly modified, the anterodorsal process is well developed. There are many protruding nodules at the anterior part. This fish does not have a rostral barbel, and the nerve foramen on the maxillary is small (it probably supplies the nerve for the snout). The joint between maxillary and premaxillary is similar to that in *Tylognathus*.

In *Labeo* (fig. 35,36), from the three species examined, there is much similarity within the genus but many modifications from the previously mentioned genera. The posterodorsal process is prominent and directed upwards and inwards; this character is unique for *Labeo*. The anterior part of the maxillary is expanded dorsoventrally, with a well developed anterodorsal process. The rostral process and the prevomerine process are short but thick and strong. The posteroventral process is simple (not hooked), but the posterior part of the premaxillary has a groove which fits into the posterior edge of the maxillary. This derived character unites *Osteochilus* and *Labeo* together.

In *Osteochilus* (fig. 36,37), the posterodorsal process of the maxillary is not produced as in *Labeo*. The posterior part of the maxillary forms somewhat of a half diamond shape. The anterior part is quite slender and without an anterodorsal process, but the prevomerine process is well developed; the rostral process is quite short and directed inward. There is a deep depression on the ventral middle part (external) of the maxillary, where the nerve foramen hinding underneath the groove. The posteroventral process of the maxillary is simple like that in *Labeo* The posterior process of the premaxillary is hooked (outward) under the posterior process of maxillary; this hook is a derived character unique in *Osteochilus*.

In Garrini (*Crossocheilus* and *Garra*, fig. 37), the maxillary has a well developed nerve foramen, and lacks an anterodorsal process. The overall shape is similar to that in the primitive Labeinae (*Barbichthys*, *Tylognathus*, and *Cirrhinus*). The maxillary and premaxillary in this group are highly modified at the anterior ventral edge by being expanding horizontally to form a thick jaw. The rostral process of the maxillary is long and vertically directed in *Garra*, but it is rudimentary in *Crossocheilus*. The posterior process of the maxillary is hooked inward over the posterior part of premaxillary. The posterior part of the premaxillary is thick and strong. The thickening of the upper jaw of Garrini is a derived character that unites the group.

The Lower Jaw

The lower jaw of the labeine genera is different from that of other cyprinids. The coronoid process of the **dentary** is always anterior and associated with the head of the dentary (posterodorsally in Barbinae), and makes the lower jaw club-like in appearance. The club-shaped lower jaw bone is a derived character that separates Labeinae from Barbinae. Labeine genera show a high degree of modification in the shape of the lower jaw as summarized below.

In *Barbichthys* (fig. 38),the lower jaw is hooked and has a short precoronoid arm, which is similar to the condition in Barbinae. However the coronoid process is somewhat anterior, not posterior, as in Barbinae.

In *Tylognathus, Cirrhinus,* and *Labeobarbus* (fig. 38), the anterior process is hooked inward to form a symphysis similar to *Barbichthys*, but the precoronoid arm is much longer. There are four pores on the mandibular lateral line canal on the dentary. The tip of the dentary is expanded into a knob on the symphysis in *Cirrhinus* and *Labiobarbus*, but not in *Tylognathus*.

In *Lobocheilus* (fig. 41), the coronoid process is associated with the head of a club-shaped dentary bone and lacks a hooked process at the symphysis. Instead, there is a wide symphysis formed by the head of the dentary on both sides. The mandibular lateral line canal of the dentary bears three pores.

In *Labeo* (fig. 39), the head of the club-shaped dentary bone is somewhat rounded and there is a small symphysis area. The lower jaw of the three species examined is quite similar. The mandibular lateral line canal of the dentary bears two pores.

In *Osteochilus* (fig. 40), the head of the club-shaped dentary bone bends inward and forms a spoon-shaped head. The coronoid process curves dorsoposteriorly, and the precoronoid arm is long in most species. In the *Osteochilus melanopleura* group, the lower jaw is triangular (lateral view), with a long horizontal symphysial area, the bones of the two sides forming a scoop-shaped lower jaw which raises the mouth opening to an almost superior position. This condition is considered to be the most derived form in this genus. The mandibular lateral line canal of the dentary bears only one pore.

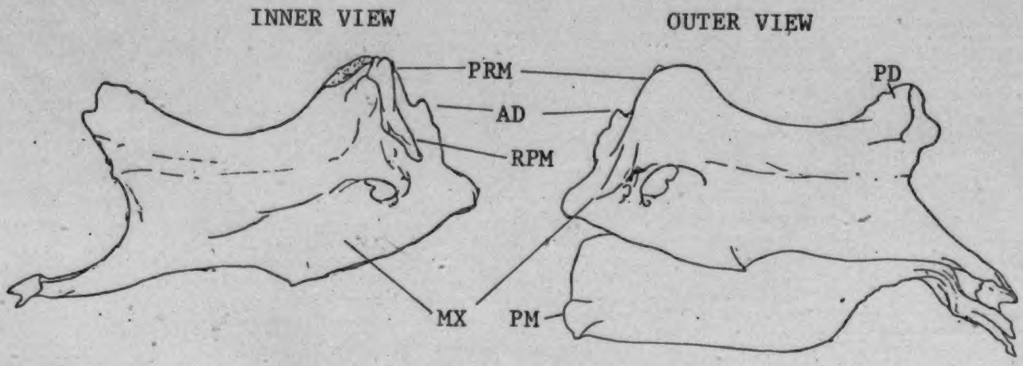
The distal end of the **angular** which is attached to the inner surface of the dentary is divided into two pointed tips. Of These two points, the outer one is usually shorter than the inner one in all the above genera. However in Garrini (*Crossocheilus* and *Garra*) the outer tip is longer than the inner one. The mandibular lateral line canal of the dentary bears one pore in this tribe.

In *Crossocheilus* (fig. 41), the head of the dentary is similar to that of *Osteochilus*, but the coronoid process is less produced and the ventral part of the dentary head has a shield-like appearance.

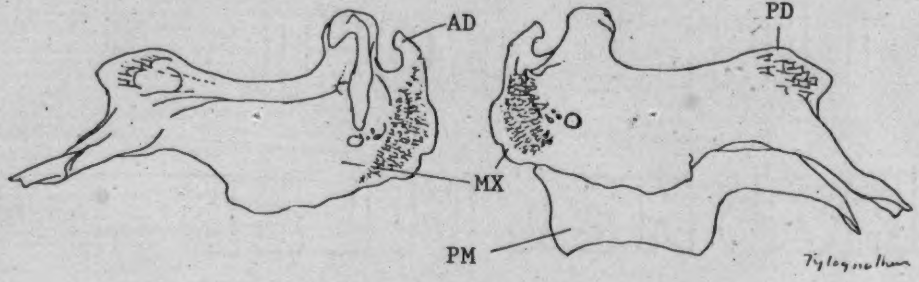
In *Garra* (fig. 41), the lower jaw is highly modified, the precoronoid arm is short but thick and wide. The symphysial arm is long and slender and joins to the main strut at a right angle. The anteroventral part has a shield-like appearance similar to *Crossocheilus*.

Branchial Region

The bones of the branchial region are similar throughout the subfamily, except in three genera, *Tylognathus, Labeo* , and *Osteochilus*. The absence of the first basibranchial in these three genera is considered to be a derived character which unites *Labeo* and *Osteochilus* together. From studying the distribution of other characters I belive that *Tylognathus* gains this character independently.


INNER VIEW
OUTER VIEW
PRM
AD
RPM
PD
MX
PM

Barbichthys laevis


AD
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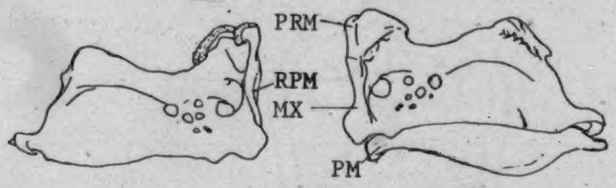
Tylognathus

Tylognathus behri


PRM
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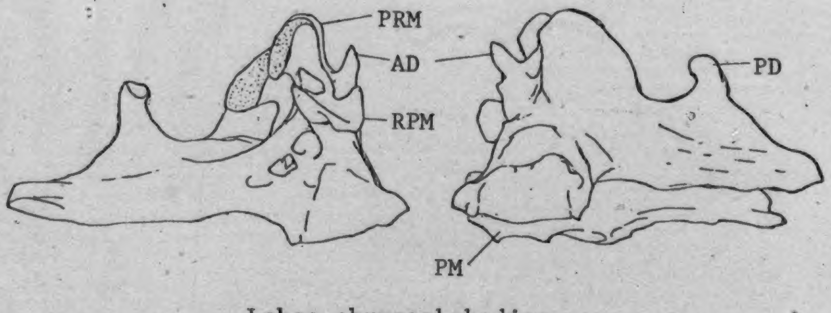
Chirrhinus chinensis


PRM
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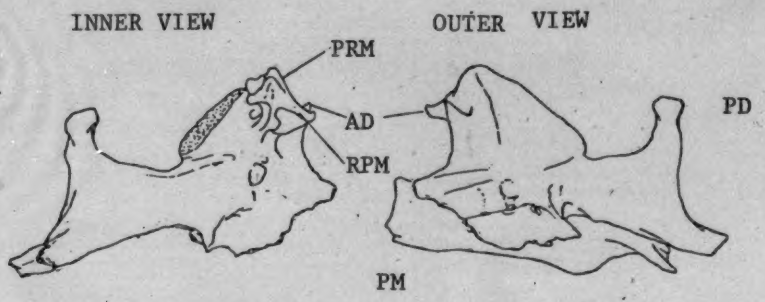
Labeo chrysophekadion

Fig. 35 Upper jaw bone (maxillary, and premaxillary)


INNER VIEW
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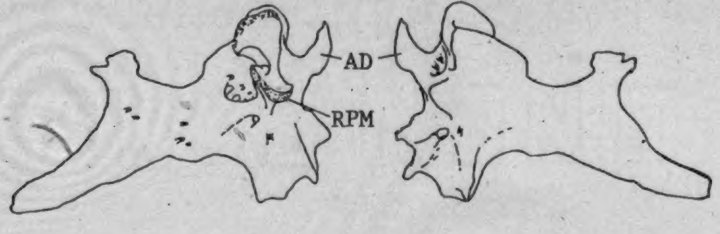
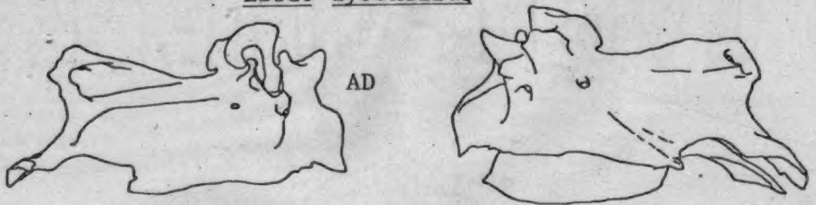
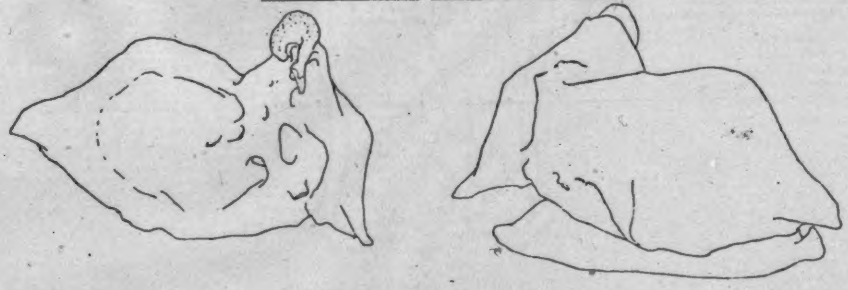
Labeo rohita



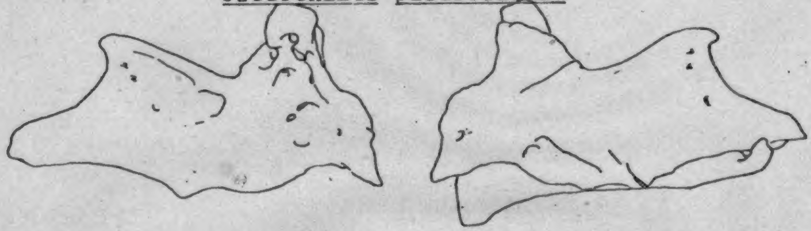
Labeo dyocheilus



Lobocheilus quadrilineatus



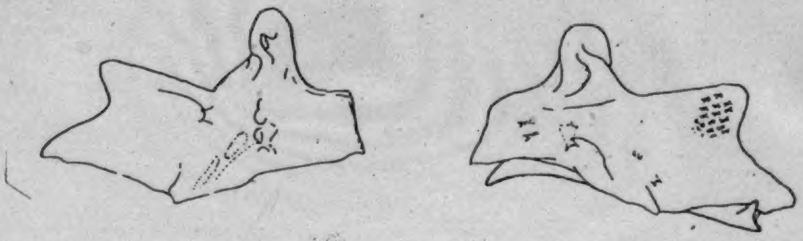
Osteochilus pleurotaenia



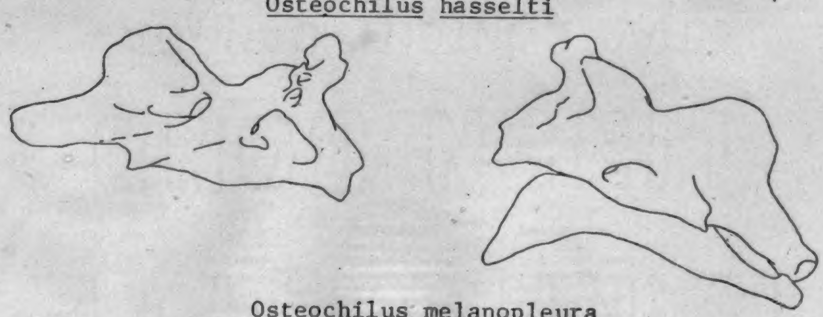
Osteochilus triporus

Fig. 36 Upper jaw bone (maxillary and pre maxillary)

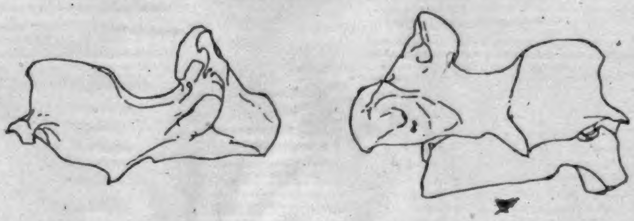
INNER VIEW OUTER VIEW



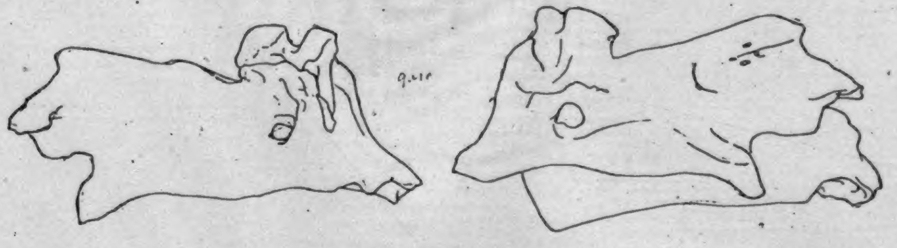
Osteochilus hasselti



Osteochilus melanopleura

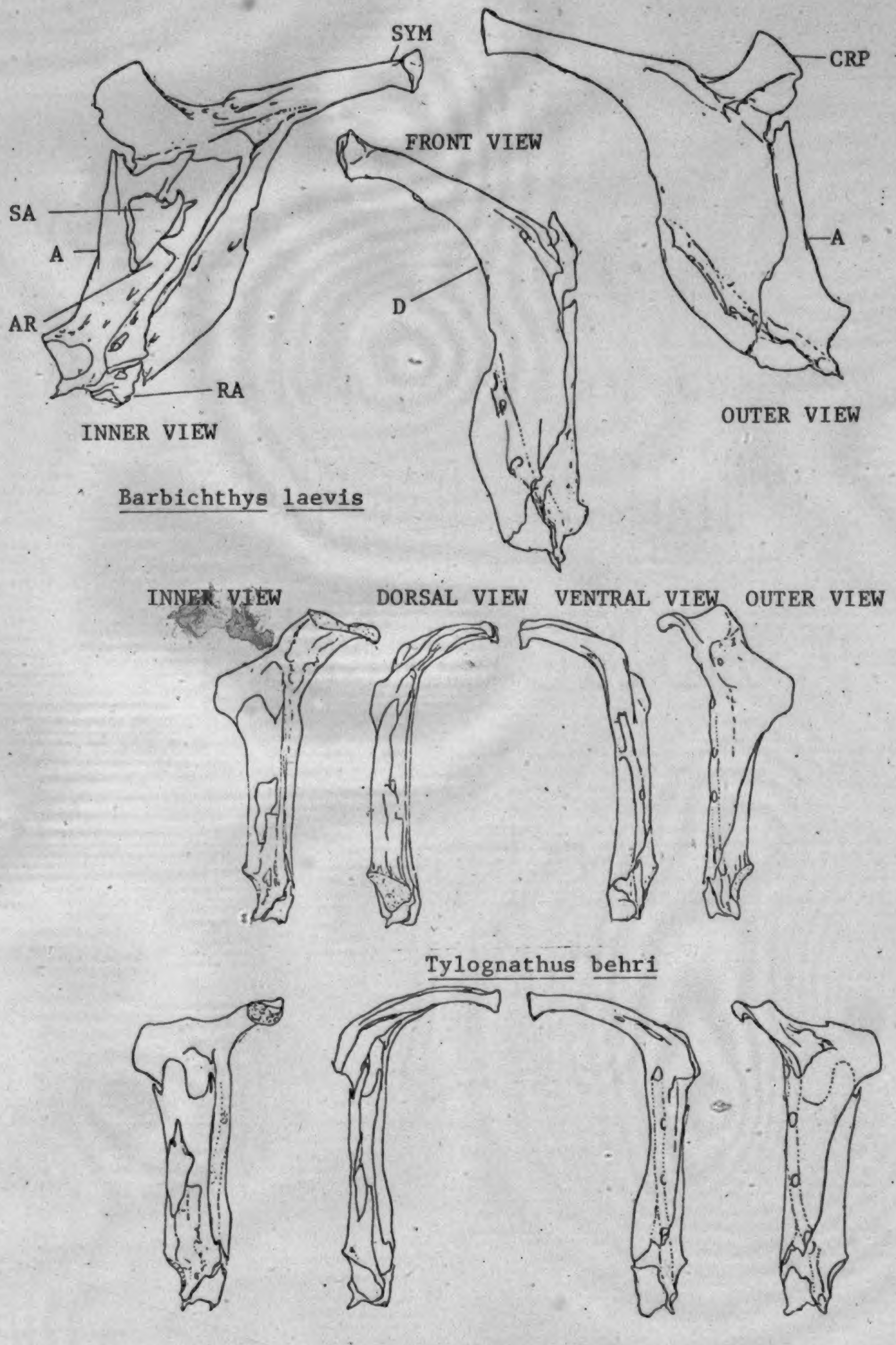


Crossocheilus reticulatus



Gara fuliginosa

Fig. 37 Upper jaw bone (maxillary and premaxillary)


SYM
CRP
FRONT VIEW
SA
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A
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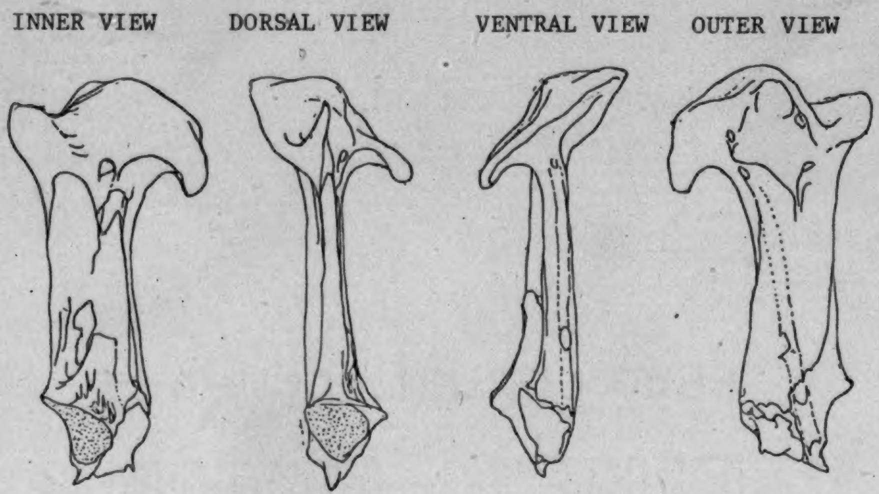
AR
RA
INNER VIEW
OUTER VIEW
INNER VIEW
DORSAL VIEW
VENTRAL VIEW
OUTER VIEW

Barbichthys laevis

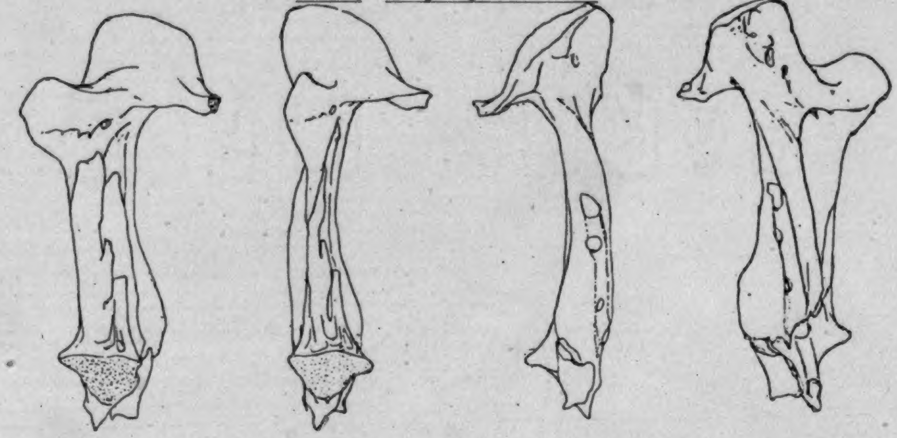
Tylognathus behri

Cirrhinus chinensis

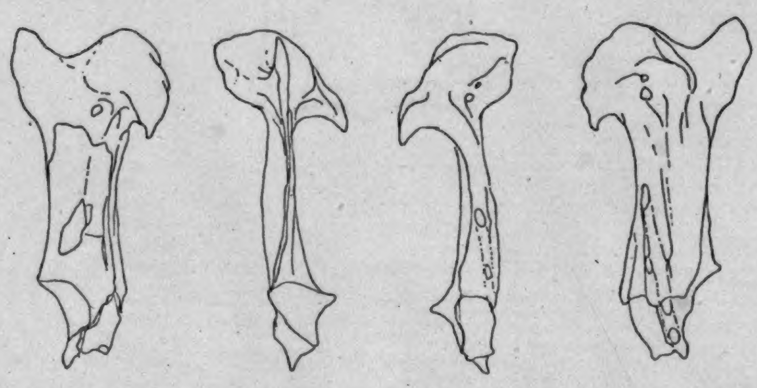
Fig. 38 Lower jaw bone


INNER VIEW
DORSAL VIEW
VENTRAL VIEW
OUTER VIEW

Labeo chrysophekadian

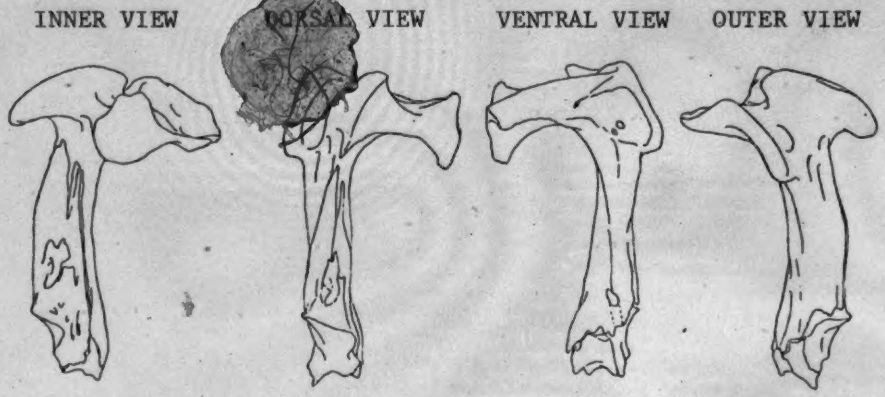


Labeo rohita

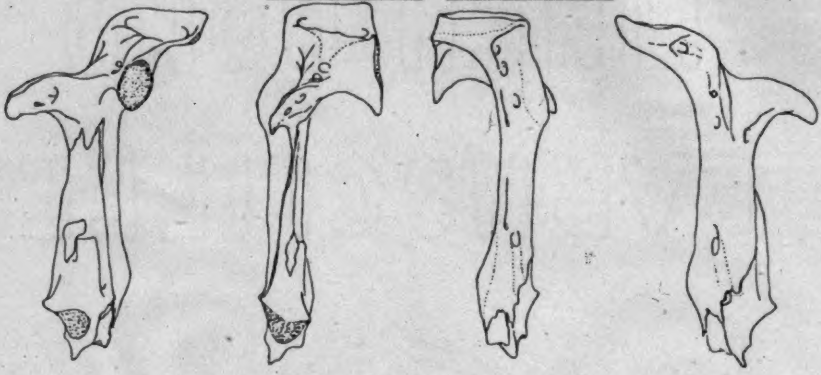


Labeo dyocheilus

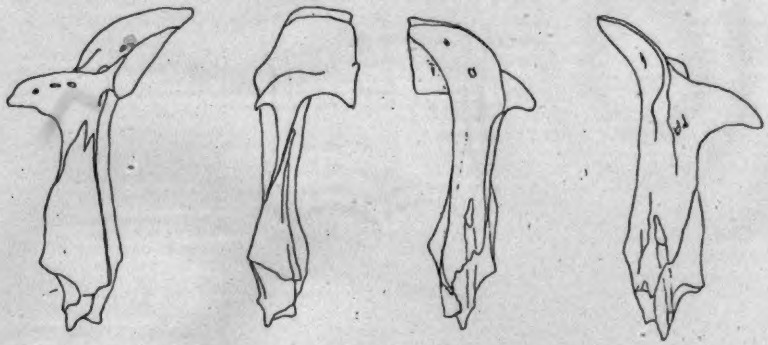
Fig. 39 Lower jaw bones


INNER VIEW
DORSAL VIEW
VENTRAL VIEW
OUTER VIEW

Osteochilus pleurotaenia

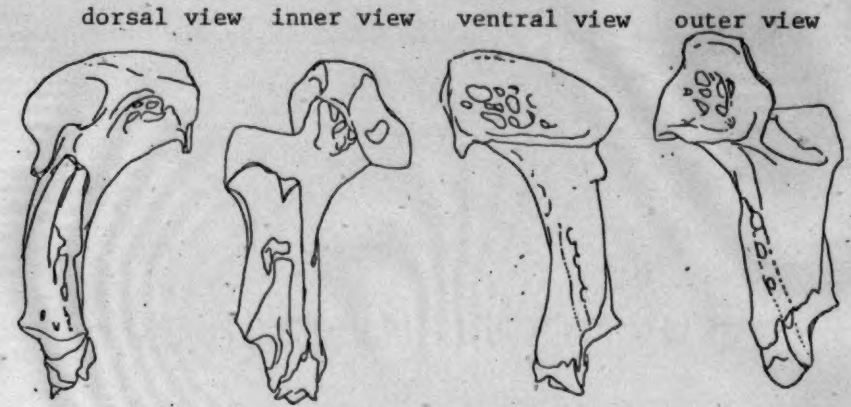


Osteochilus triporus

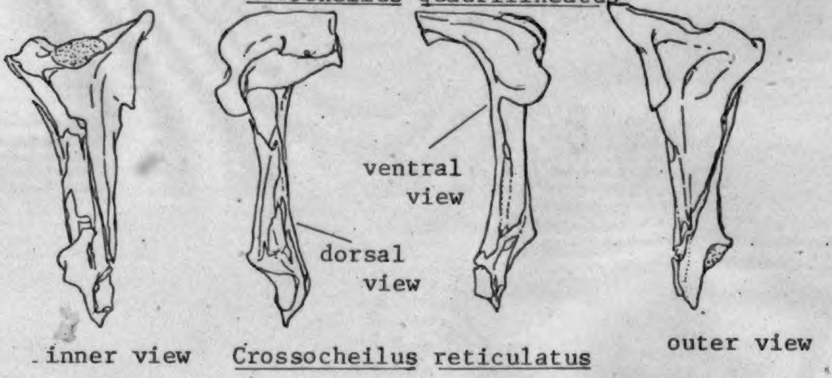


Osteochilus hasselti

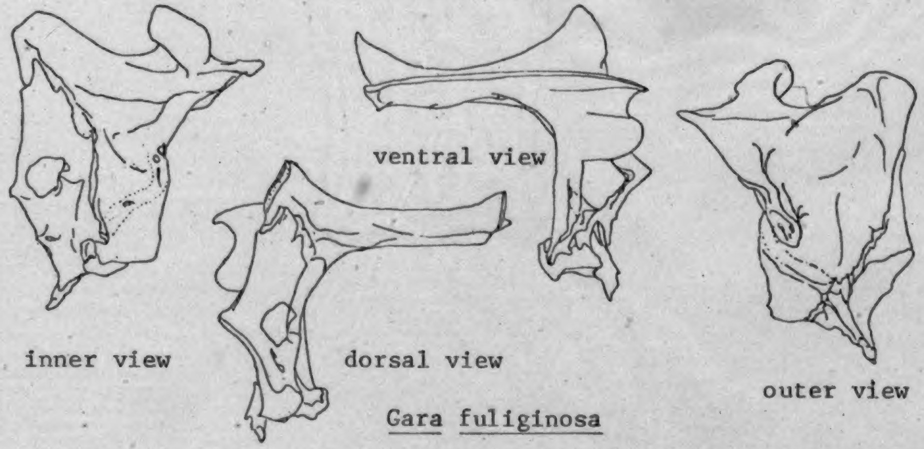
Fig. 40 Lower jaw bones


dorsal view
inner view
ventral view
outer view

Lobocheilus quadrilineatus


ventral view
dorsal view
inner view
outer view

Crossocheilus reticulatus


ventral view
inner view
dorsal view
outer view

Gara fuliginosa

Fig. 41 Lower jaw bones

DISCUSSION OF THE OROMANDIBULAR ORGAN IN LABEINAE

DISCUSSION OF THE OROMANDIBULAR ORGAN IN LABEINAE

In this thesis the term "oromandibular" refers to morphological features of the mouth and buccopharynx region. Results of the following osteological studies were used to understand and describe cyprinid oromandibular morphology: Sarbahi, 1932; Harrington, 1955; Ramaswami, 1952, 1955; Saxena, 1966; Greenwood & Jubb, 1967; Sorescu, 1970; Soresco, 1971; Vandewelle, 1975; and Howes, 1978.

There are numerous studies which deal with oromandbular soft anatomy: e.g. i) in teleosts, in general: Khanna & Mehrotra, 1970; Kapoor et al., 1975; ii) in European cyprinids: Pictet, 1909a,b; Al Hussaini, 1949; Wunder, 1971; Teodorescu-Balteanu, 1971; iii) in tropical old world cyprinids: Hyrtl, 1864; Matthes, 1963; Kamal, 1964; Verigina, 1969; Khanna & Singh, 1966; Hoda & Tsukahara, 1971; Kilaski & Bigaj, 1971; Tanaka, 1971; King, 1975; iv) in labeine cyprinids: Rauther, 1928; Minzenmay, 1933; Sarbahi, 1939; Majumdar, 1952; Girgis, 1952a,b; Saxena, 1959, 1960; Majumdar & Saxena, 1961; Matthes, 1963; Lal et al., 1964; Das & Nath, 1965, 1969; Sehgal, 1965b; Moitra & Sinha, 1972; Sinha & Moitra, 1975; Reid, 1978.

Allis (1917, 1932) produced a classification scheme for what he considered to be homologous lip folds in gnathostomes. The validity of this scheme is dependent upon assumptions about the homologies of nasal apertures throughout the gnathostomes. The arguments which Allis presents are complex, nevertheless it appears that most of his proposed nasal aperture homologies are doubtful (Miles and Young, 1977:146-147). For this reason I have not attempted to place my interpretation of cyprinid oromandbular morphology in the context of Allis's system. Anson (1929) seems to have based his interpretations of the morphology of "lips and labiel villi" of vertebrates on the concepts of Allis (1917). According to Anson (1929:p.358, fig.3)

> "the upper lip in carp (*Cyprinus*) is developed at a point anterior to that where the premaxillary teeth should erupt and the lower lip is presented as a thick rounded and somewhat everted margin to the jaw."

There are difficulties, however, if one uses this concept to interpret the complex lip folds seen in labeine cyprinids. Minzenmay (1933) gives a particularly detailed and wide ranging survey of the gross morphology and histology of the oromandbular region in cyprinids. I have used many of the morphological principles postulated by Minzenmay (1933).

OROMANDIBULAR MORPHOLOGY

External Morphology

1. Rostral Fold, Rostral Flap, or Rhinal Lobe

A rostral fold ("rostral kappe" of Minzenmay, 1933) is present in all cyprinids, although it varies considerably in its degree of development. In Barbinae it is usually a simple transverse crease in the flesh overlying the maxillary bones. In Tylognathini, it extends ventrally from the tip of the snout to partially overlie the premaxillary bones. In Garrini the rostral fold is incrassate and down-grown so that it completely overlies the upper lip and premaxillary bones. Matthes (1963:16) mistook the rostral fold for the upper lip, when he stated that "a rostral flap is absent or but poorly developed" in *Garra* (see item three for definition of upper lip which is rudimentary in *Garra*). In Labeini the fold may be down grown but it always tends to be skinny; in *Labeo* during early ontogeny the fold undergoes lateral detachment to form a rostral flap, but in *Osteochilus* it is similar to those found in Tylognathini.

In Barbinae and Tylognathini and in the majority of Labeini the ventral margin of the rostral fold is straight-edged while in Garrini and in some *Labeo* the ventral margin is indented.

In Barbinae the anterior face of the rostral fold is often free of keratinized epidermal tubercles whereas in all tribes of Labeinae, conical or acanthoid tubercles are usually present. The outer face of the rostral fold is free of macroscopic papillae in Barbinae, Tylognathini, and Labeinae. In Garrini, macroscopic granuloid papillae form a band along the invecked margin. In *Epalzeorhynchos* and *Garra* the band is pronounced. Granuloid papillae may be lightly keratinized in *Garra* and bear micro-spines (see Hora, 1922; Rauther, 1928; Saxena, S. 1959, 1960).

The inner face of the rostral fold (where developed) is smooth in Barbinae, Tylognathini, and Labeini whereas in some Garrini (*Garra*) the inner ventral border may be fluted more or less transversely. There is no muscularis layer in the rostral fold (Saxena,

S. 1959). The rhinal furrow is a groove which, on each side of the head, marks off the lateral boundary to the rostral fold (or flap). It is deeply incised in some Tylognathini, Labeini and , Garrini. In *Epalzeorhynchos*, there is a hollow depression on each side of the antero-lateral aspect of the snout. This hollow is placed just in front of the anterior margin of the underlying lacrymal bone and just behind the base of the anterior barbel. Each of these hollows contains a tuberculate "rhinal lobe" (see Smith, 1945; Alfred, 1971). Each lobe fits closely into its hollow and is partially concealed. A rhinal lobe lifted clear of the hollow that contains it has the appearance of a sturdy barbel and is very distinctive. There are very small epidermal tubercles scattered over the anterior (exposed) surface of each lobe, and a single large ancylate tubercle may be developed on the tip. If this terminal tubercle is absent a pore-like tubercle scar remains, which could convey the misleading impression that the rhinal lobe has a central fistula. Histological sectioning shows, however, that the tip contains a pit formed by invagination of the epidermis into the underlying connective tissue of the dermis. This pit is of a type commonly associated with the generation of larger forms of tubercle (Reid, 1978).

2. Anterior Barbels

Barbels (anterior and posterior pairs) are present 21-27 days after hatching in *Labeo calbasu, L. gonius*, and *L. rohita* (Mookerjee, 1945). Chakrabarty & Murty (1972) found barbels to be well developed in 15 day old specimens of *L. rohita* and *Cirrhinus*.

The length of the anterior barbels varies interspecifically in both Barbinae and Labeinae. In adult *Barbus bynni*, for example, the anterior barbel length is an average of 4 % of SL whereas in adult *B. microbarbia* the anterior barbels are rudimentary (Banister, 1973). In many species of *Labeo* the anterior barbels are well developed in juveniles but become rudimentary or absent in adults (see numerous examples in Hora & Niara, 1942; Banarescu, 1972: 255). In all *Osteochilus*, anterior barbels are well developed in both juveniles and adults, although the ratio of barbel length to standard length is greater in juveniles than in adults.

In most barbine and labeine species the barbels are pigmented so that they appear as dark as or considerably darker than the skin of the adjacent snout.

The anterior barbels are supplied on each side by conspicuous nerve tracts (revealed in dissection). This tract is a subdivision of the superior maxillary ramus of the trigeminal nerve (V) (Krawarik & Suss, 1936; Dorier & Bellon, 1951/52). Each nerve tract passes to the barbel via a foramen situated just above an anterior process of the maxillary bone (Fig. 35-37).

The position of the barbels on the snout varies considerably between species of both Barbinae and Labeinae. This variability is partially due to the differences in the relationship between the rostral fold and underlying maxillary bones. The following types of insertions can be recognized (terms used by Reid, 1978).

i). Sub-rostral barbels which originate below the rostral fold and which lie exposed on each side of the snout with (in life) their tips directed posteroventrally e.g., *Barbus, Labeobarbus, Cirrhinus*, and *Osteochilus*.

ii). Antero-rostral barbels which grow out through and project forward from the (down grown) rostal fold (e.g. *Garra* and *Epalzeorhynchos*)

iii). Latero-rostal barbels inserted on the ventro-lateral face of the rostral flap (e.g., *L. chrysophekadian, L. nigripinnis*, and *L. umbratus*, etc).

iv). Antero-rhinal barbels inserted anterodorsally in the rhinal furrow (e.g., *L. cubie* and *L. forskali*.)

Raffin-Peyloz (1955) gives a historical review of the study of cyprinid barbel histology (See also Sato, 1937; Von Lukowics, 1966; Hoda and Tsukahara, 1971: 427, fig17,18). In transverse section the barbels (anterior and posterior) show a'dermal core' occupied by nerve bundles and blood vessels, a 'middle zone' of pigment cells and fibroblasts (associated with an inner longtitudinal and outer circular layer of collagen), and a 'peripheral zone' of stratified epithelium (associated with taste buds and a variable number of mucus cells). Hoda and Tsukahara (1971:490) note that in *Cyprinus*, at least, the taste buds are of three types (i.e., with buds which are protruded, truncated, or depressed). Tandon & Arora (1970) find taste buds to be absent from the barbels of

Labeo dero (=*Tylognathus dero*). In cyprinids, unlike siluroids , the dermal core has no cartilaginous rod (Sato, 1937) or muscularis layer (although the muscularis layer has been reported in *Gobio* by Raffin-Peylos, 1955). Siluroids may have in addition an external retractor tentaculi muscle associated with the barbels (von Lucowics, 1966).

3. Upper Labial Fold (Upper Lip)

The upper labial fold occurs in all species of Labeinae but not in Barbinae. The fold is a skinny crease of tissue formed beneath the rostral fold and dorsal to the edge of the upper jaw. The fold is not well developed in *Barbichthys* and *Tylognathus* but it is easily seen in *Cirrhinus* and *Labiobarbus*.

In *Osteochilus* and *Labeo* the fold is variably hypertrophied and a separate inner and outer region can be distinguished; the outer region comprises a palisade of more or less sub-conical papillae. Lip papillae are developed in three-week-old larvae of *Labeo gonius* (Ahmad, 1944) and in 15 day old *L. rohita* and *Cirrhinus mrigala* (Chakrabarty & Murty, 1972). In at least *Labeo* and *Cirrhinus*, fine nerve fibres supply papillar taste buds (Sarbahi, 1939:p98; Girgis, 1952:p335; Seghal, 1965:p265, Fig.3). Seghal & Salaria (1970) found the density of taste buds to be 8-12 per square millimetre in this region in *Cirrhinus* while Moitra & Sinha (1972,Fig. 1,2) record papillar taste bud densities of 36-40 per square millimetre in the same species.

Papillae are best developed medially and in *Osteochilus* they may be replaced laterally by a fringe of skinny projections (fimbriae) with a large number of taste buds present (see fig. 44,46). In some species of *Labeo*, papillae are absent (e.g. *L. coubie*, and *L. forskali*).

The inner region has an expanded surface which is only clearly visible in ventral view. This surface has a series of confluent ridges (termed costae or transverse plicae by Boulenger, 1909:p301, and by Matthes, 1963) which radiate from the median plane. These ridges are crenulated in *Labeo*. In some species, (*L. fimbriatus* and *L. niloticus*) these costae are coarsely crenulated - each crenulation being slightly covered with keratin. In the other species (*L. coubie* and *L. forskali*), the costate surface is extensive and the costae are finely crenulated (Reid: 1979). In the *Osteochilus microcephalus*, *O.waandersi*, and *O. triporus* groups the costae are long, slender, and divided into two parts with the anterior part consisting of smooth epithelium and taste buds and the posterior part consisting of unicellular keratinized projections called unculi (see fig. 48). In another group, *O. hasselti* and *melanopleura*, the costae are short and mound-shaped and the taste buds and unculi are mixed on the top of the costae (see fig. 45 and fig. 47).

Matthes (1963:16) misinterpreted the rostral fold of *Garra* as the homologue of the "fringed upper lip" in *Labeo*. In Garrini the upper labial fold is only conspicuous in juveniles (e.g., it is well-developed 5 days after hatching in *Garra ceylonensis*,Jones 1941; my observation of *Crossocheilus* was similar) and rudimendary in adults. In early ontogeny it is a skinny fold with a variably developed scalloped ventral margin, but this tissue never becomes enlarged (as in *Labeo* and *Osteochilus*) and it regresses with age (Hora 1921, p643; Rauther 1928,p68,74; Minzenmay, 1933,fig.36).This reduction is accompanied by a hypertrophy and downgrowth of the rostral fold so that in adults the upper labial fold is entirely or almost entirely covered.

4. **Upper Jaw and Callus Sheath** (Fig. 42,49)

In Barbinae and Labeinae the edge of the upper jaw is a curved fleshy ridge and is supported by the anteroventral edge of the underlying premaxillary bones. In *Barbus* each premaxillary has a mesial ascending pedicel (Mathes, 1963:20) but in *Varicorhinus*, *Garra*, and *Labeo* this is poorly developed. In Labeinae the premaxilla have a loose median symphysis, which sandwiches a thin pad of fibro-cartilage (Girgis, 1952a, fig.5a). The upper jaw has an overall beak -like appearance in Labeini and Garrini whereas in Barbinae and Tylognathini the contours are softened by a hypertrophy of the corium (dermis and epidermis) (See Matthes, 1963 ,pl 9a; Banister, 1973,fig.78).

In Labeini and Garrini the beak-like appearance and texture is enhanced by the presence of a callus layer of keratin which forms a deciduous sheath over the epidermis (Minzenmay, 1933, fig 43; Girgis, 1952b:335-336, fig.7). The keratin layer is thickened along the cutting edge of the jaw (fig. 49).

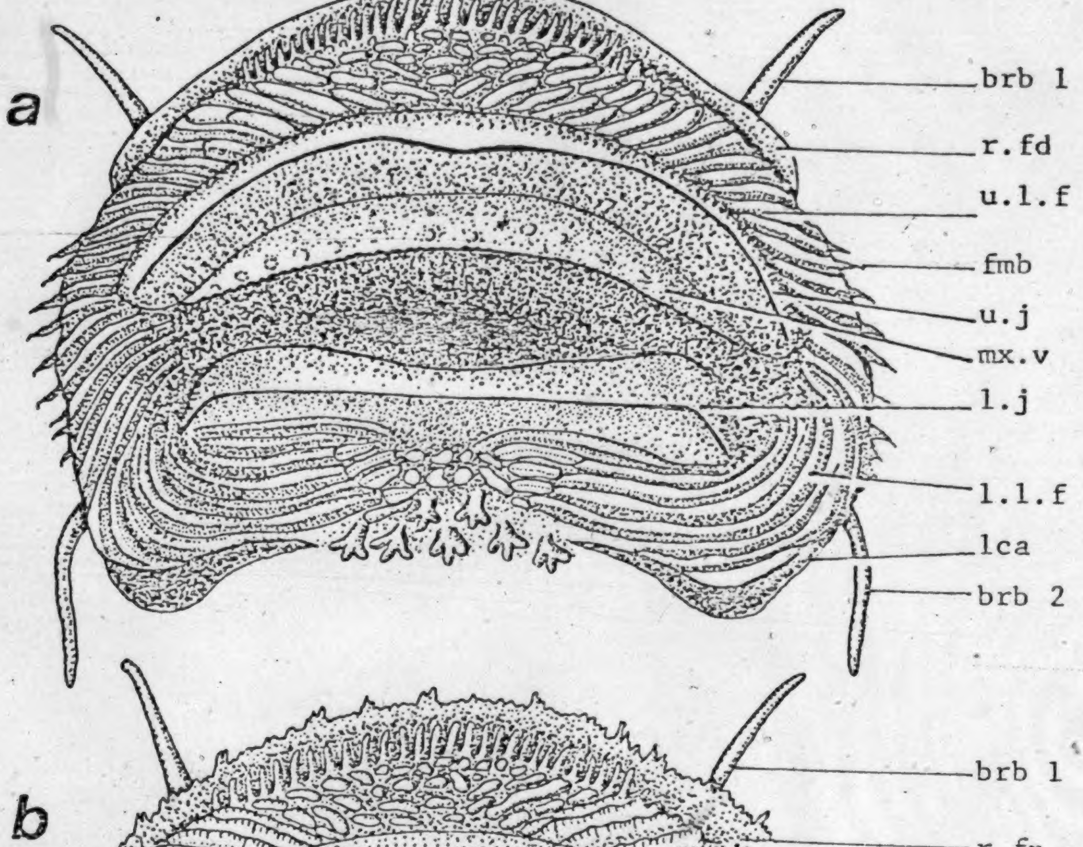

a
brb 1
r.fd
u.l.f
fmb
u.j
mx.v
l.j
l.l.f
lca
brb 2
b
brb 1
r.fp
u.l.f
u.j
mx.v
l.j
l.l.f
lca
brb 2

Fig. 42

Ventral view of mouth region (a) Osteochilus, (b) primitive Labeo
(brb 1 = rostral barbel, r.fd = rostral fold, u.l.f = upper labial fold, u.j = upper jaw, mx.v = maxillary valve, l.j = lower jaw, l.l.f = lower labial fold, lca = lacuna(pit or hollow), brb 2 = maxillary barbel)

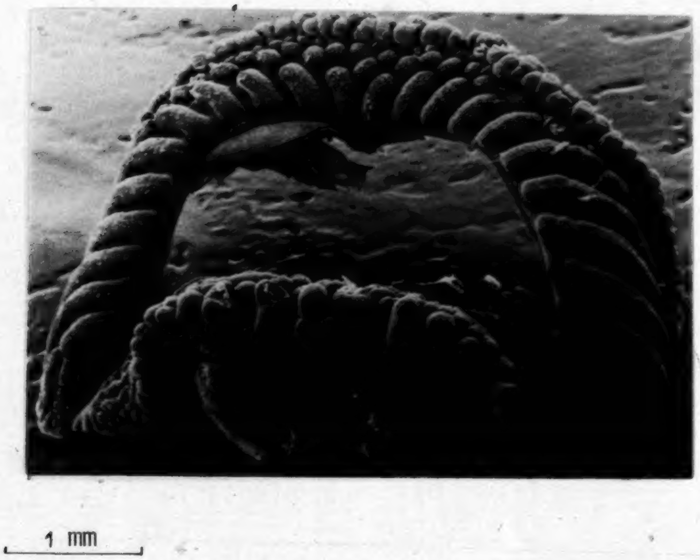


Fig. 43 Primitive condition of lip costae on the upper lip (labial fold) and trilobed papillae on the outer region of lower labial fold (Osteochilus microcephalus, NIFI uncatalogued, 53.5 mm SL).

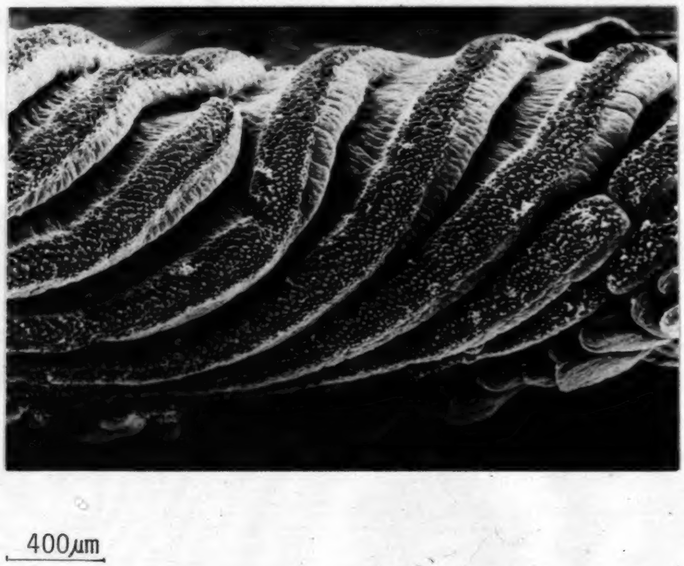


Fig. 44 Advance type of lip costae in Osteochilus that live in fast moving water habitat (O. waandersi, NIFI uncatalogued, 150 mm SL).

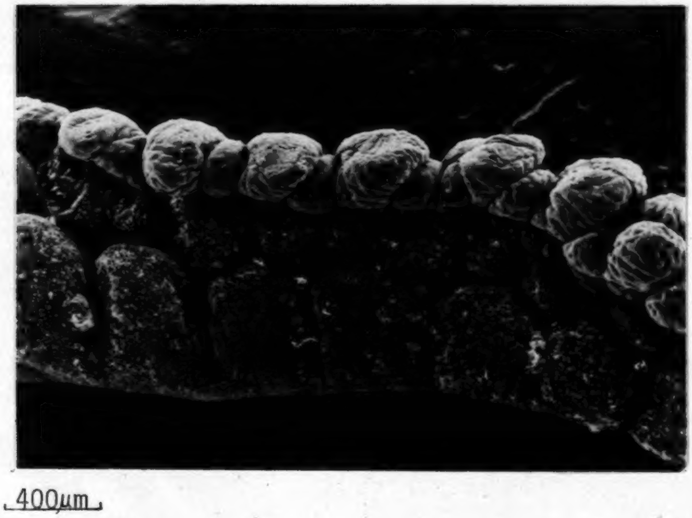


Fig. 45 The lip costae in the intermediate state (Osteochilus hasselti, NIFI uncatalogued, 116.8 mm SL).

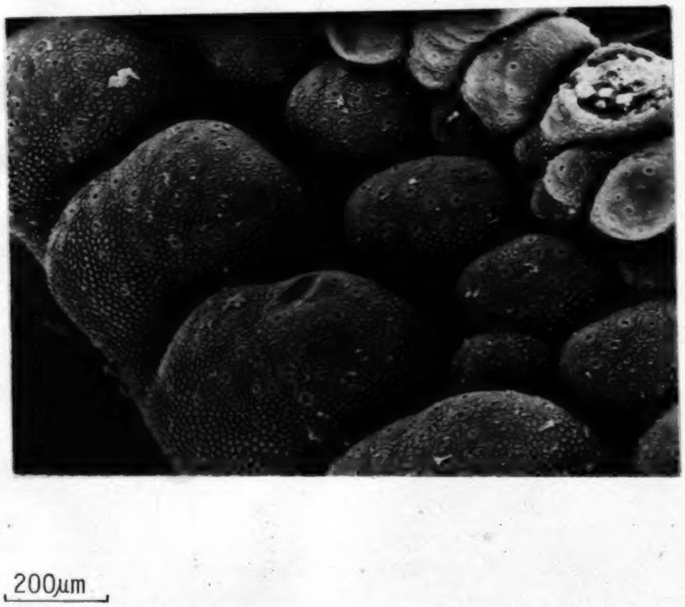


Fig. 46 Lip costae on the ventral side of the upper labial fold of Osteochilus borneensis, shows the taste buds on top. (NIFI uncatalogued, 57.2 mm SL)

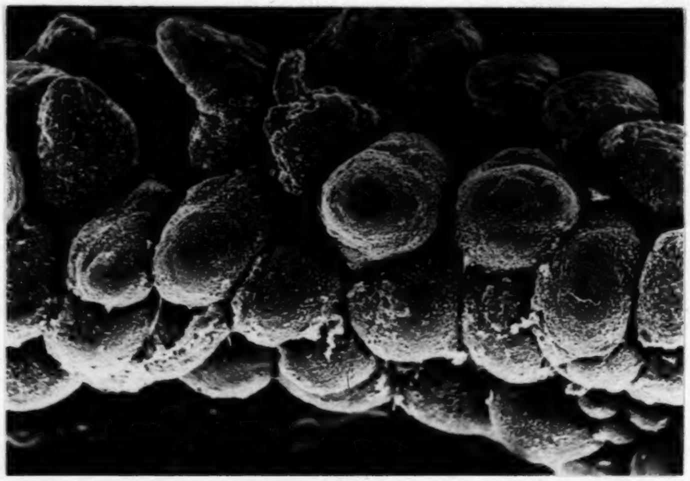


Fig. 47 Advanced condition of lip costae of Osteochilus which live in still or slow moving water habitat (O. melanopleura, NIFI uncatalogued, 141.9 mm SL).

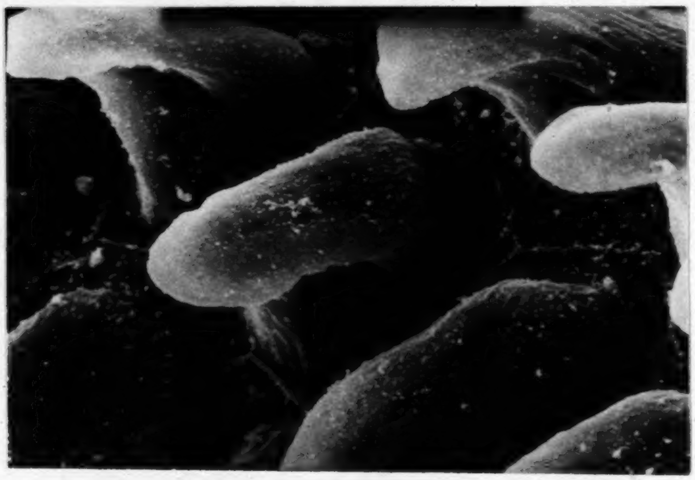
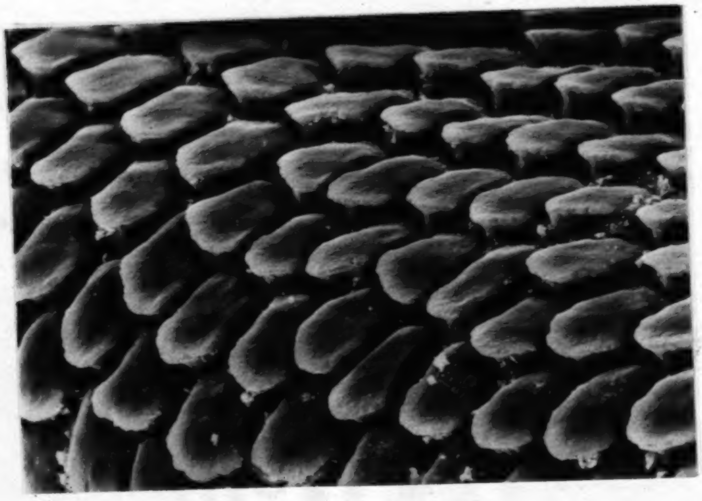


Fig. 48 Unicellular unculi on the costae of the upper labial fold in Osteochilus sarawakensis (FMNH 68532, 83.4mm SL).



20μm

Fig. 49 Microstructure of the callus sheath on the upper jaw of Osteochilus spilurus (KCTR 76-42, 47 mm SL).

5. **Maxillary Valve** (Fig. 42)

This guards the entrance to the buccopharynx. It is a diaphragm which extends out from along the base of the inner edge of the jaw. The maxillary valve is moderately well-developed in Barbinae. The morphology and histology of the maxillary valve is more or less uniform throughout the cyprinids (Mitchell, 1904; Girgis, 1952b; Kapoor, 1956; Saxena, D., 1959; Das & Subla, 1964; Hoda & Tsukahara, 1971, fig. 22, 27). The valve contains a high proportion of elastic connective tissue and the outer face often has soft globose papillae which contain numerous taste buds (there is no corresponding mandibular valve in Labeinae & Barbinae except in *Barilius* (Rasborinae).

6. **Mouth Opening**

The mouth opening in most Barbinae is sub-terminal to ventral whereas in most Labeinae it is ventral (inferior). In Labeinae there is, during early ontogeny, a ventral shift in the position of the rictus (Jones, 1941(*Garra*); Ahmad, 1944(*L. gonius*); Mookerjee, 1945:401-402 (*L. calbasu, L. gonius, L. rohita*); Fryer & Whitehead, 1959 (*L. victorianus*)).

7. **Lower Jaw and Callus Sheath**

In Barbinae and Labeinae the transverse fleshy ridge of the lower jaw is a relatively smooth rim, supported by the anterior edge of the underlying dentary bones. The shape of the leading edge of the dentary varies considerably within both Labeinae and Barbinae and consequently there is variation in the external form of the lower jaw. In most Barbinae and Tylognathini each dentary is, in dorsal aspect, essentially hook-shaped (fig. 38). There is an ascending ('coronoid') process placed dorsoposteriorly in Barbinae (see also Ramaswami, 1955, fig 15; Matthes, 1963, pl 9b), dorso-anteriorly in Tylognathini and Garrini (fig. 38) (see also Ramawami, 1952, fig 11, 12), and incorporated in the head of the club shaped dentary in *Labeo* (fig. 39)(see also Sarbahi, 1932, fig 19; Girgis, 1952a, fig 6; Ramaswami, 1952, fig 16; Greenwood and Jubb, 1967, fig. 9), *Osteochilus* and *Lobocheilus* (fig. 40,41). This latter development gives the pre-coronoid arm a club-like appearance.

In some Barbinae the contours of the lower jaw, as in the upper jaw, are softened by a thickening of the corium layer (dermis & epidermis). In many *Barbus* species this jaw tissue can be grossly hypertrophied and extended postero-ventrally (e.g. *Barbus tor* and *B. putitora* (Asia); *B. bynni, B. oxyrhynchus,* and *B. intermedius* (Africa)) (See Matthes, 1963, pl.9a; Banister, 1973, fig 78). In *Cirrhinus* and *Labeobarbus* the corium is not fleshy and the dorsally directed symphysial process is visible superficially.

In some Barbinae and in most Labeinae a callus layer of keratin forms a sheath over the corium. Earlier workers erroneously suggested that the sheath was cartilaginous (Mathias, 1920). In Labeinae, the sheath is deciduous. Salvaraj et.al (1972) found the sheath to be present in *Labeo boggot* of 25 mm.SL. The keratin layer is thickened along the edge of the lower jaw, which giving the characteristic chisel-like jaw of *Osteochilus, Labeo, Lobocheilus,* and *Garra* etc.

8. **Lower Labial Fold**

This occurs in Labeinae but not in Barbinae except for *Prolabeo.* The fold is in a thin crease formed behind the leading edge of the lower jaw. The simple condition is seen in adult *Cirrhinus* and *Labeobarbus.* In *Tylognathus* and *Barbichthys* the fold curves along and partially covers the outer face of the lower jaw. In *Tylognathus,* course papillae are scattered along the inner edge of the fold. In Garrini the lower fold (as is the case with the upper fold, see under 3) is regressed in adults (Matthes, 1963). In *Lobocheilus* the lower fold hypertrophies forming a movable superficial part consisting of a thick fleshy pad which completely covers the lower jaw.

In adult *Osteochilus* and *Labeo* the upper and lower folds are continuous at the corners of the mouth and form a sucker-like ring. The lower fold (as is the case with the upper fold, see under 3) has an outer and inner region. In species of *Osteochilus* and in some species of *Labeo* the outer region comprises a median cluster of conspicuous tri-lobed papillae. In the majority of *Osteochilus* the tri-lobed form is generally precise and each papillae may also have a light covering of keratin (fig. 42-43) In *Labeo* the tri-lobed form is irregular or ragged and the papillae are fleshy. Conspicuous tri-lobed papillae are found in certain Asiatic species of Labeo (e.g., *L. fimbriatus* and *L. ariza*) but not in any African *Labeo* (Reid, 1978).

In *Osteochilus*, the inner region consists of a group of single lobed papillae medially and transverse costae laterally which are a continuation of the upper labial fold. Costae and papillae at this region are also covered by the keratinized unculi and taste buds as in the upper labial fold (fig. 44,45)

9. Post-mandibular region

In both Barbinae and Labeinae there are lateral hollows (lacunae, the term used by Reid, 1978) behind the jaws. In Barbinae, Tylognathini, and Garrini the lacunae are shallow while in Labeinae they may be cavernous. In species of both *Osteochilus* and *Labeo* there are medially directed extensions but only in *Labeo* do they meet in the midline to form a continuous transverse sulcus. In Barbinae there are no medially directed extensions although in some cases a transverse crease is formed behind the hypertrophied and posteroventrally reflexed corium of the lower jaw. A distinction must be made here between post-mandibular and post-labial forms. In Barbinae, the lacunae (and the transverse crease where it occurs) are immediately behind the jaw whereas in Labeinae the lacunae (and transverse sulcus where it occurs) form immediately behind the lower labial fold.

10. Posterior Barbels

The length of the paired posterior barbels varies interspecifically in both Barbinae and Labeinae. In most cases the posterior barbels are longer than the anterior barbels but in Garrini the converse is sometimes true. Although posterior barbels can be rudimentary they are rarely absent (unlike the anterior barbels). The ratio of barbel length to standard length is greater in juveniles than in adults.

Barbels are supplied (on each side) by a conspicuous nerve tract which is a subdivision of the mandibular branch of the trigeminal nerve (Reid, 1979). The position of the barbels varies considerably between species of both Barbinae and Labeinae.

In Barbinae the barbels originate from post mandibular lateral lacunae (see under 9) and lie exposed on each side of the head with (in life) the tip directed posteroventrally. A similar condition is seen in *Cirrhinus* and *Labeobarbus*, but in *Osteochilus* and *Labeo* the barbels are at least partially hidden within the hollow of the post-labeal lateral lacunae with their tips directed more or less ventrally or anteroventrally (in some *Labeo*).

In Barbinae, Tylognathini, and Labeini there is a distint gap between the barbels and the rostral fold. In Garrini, however, the barbels on each side are closely associated with the ventral posterolateral margin of the downgrown rostral fold; barbels in this position are separated from the regressed lower labial fold (in contrast to the condition in Labeinae).

INTERNAL ORO-MANDIBULAR MORPHOLOGY

Majumda & Saxena (1961) classify the buccopharyngeal roof of *Labeo dero* (=*Tylognathus dero*) into several zones. I have adopted a modified, abbreviated form of their classification.

Buccopharyngeal Roof

11. Vomero-palatine organ and associated structures

The vomero-palatine organ together with associated structures [2] are referred to as a vomero-palatine organ. The first published description and figure of this organ is by Steindachner (1870:562, pl7,fig 1a) in African species *Labeo coubie*. Since then this structure has been noted in other African and Asian Labeinae (Boulenger, 1907:p161; Majumdar, 1952, fig 1b; Majumdar and Saxena, 1961, fig 2; Girgis, 1952a, fig I; 1952b, fig I; Matthes, 1963, pl.IIa). The above authors did not try to assess the systematic significance of the vomero-palatine organ. Reid (1978) considered in his descriptive accounts those accounts of the organ which he considered to be of systematic importance.

The vomero-palatine organ is situated on the buccopharyngeal roof in Labeinae but not in other groups. This organ lies in a navicular depression of buccal tissue covering the ventral surface of the vomer (anteriorly), the parasphenoid bone (posteriorly) and the metapterygoid bones (laterally). This region of the buccopharynx is innervated by fine anastomoses of the facial (VII), glossopharyngeal (IX), and vagus (X) nerves (Krawarik and Suss, 1936; Dorier and Bellon, 1951/52; Ping et al., 1959; Edwards, 1930; Kappers et al.(1960). The elements of the vomero-palatine organ vary ontogenetically both within and between species, but in adults it is essentially formed from a paired longtitudinal series of overlapping transverse fleshy folds (lamellae). Each lamellar, which has a hook-shaped (unciform) tip and bluntly serrated posterior margin, hangs freely from the roof of the mouth into the buccal cavity. The anterior and posterior lamellae are generally small or rudimentary in comparison with others. Steindachner (1870;562) has compared the overall disposition of lamellae to the form of the cephalic disc in the shark sucker (*Echeneis*) and I agree with this analogy. In Labeini there are 5-9 (the majority have 7) perfectly formed lamellar pairs (fig. 50). In Tylognathini, the lamellar pairs normally are fewer (4 or 5) and the individual lamellae are larger and fleshier. In Garrini there are , at least in early ontogeny, 5-9 (majority have 7) lamellar pairs but in adults of *Garra* and *Semilabeo* the organ is regressed. A similar regression takes place in somes pecies of *Labeo* and there is complete regression in *Osteochilus*. In Barbinae the tissue of the buccopharyngeal roof consists of a series of fine longtitudinal wrinkles (Mathes, 1963, pls6b;10) in contrast to the regressed vomero-palatine organ consisting of an ovoid patch of smooth or feeble-transverse corrugations found in adult Labeinae.

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[2] Synonyms of this structure are as follows: "doppeihe von hautingen querfalton," Steindachner, 1870; "group of large papillae," Boulenger, 1907; "Comb-shaped plate," Majumdar, 1952; "Comb plate region," Majumda & Saxena, 1961; "Lamellar organ of palate," Girgis , 1952a, 1952b; vomero-palatine organ," Mathes, 1963.

The particular arrangement and form of lamellae varies between taxa. Histologically, the lamellae are rich in mucous cells while taste buds are relatively few in number. A few muscle fibres run into the lamellar submucosa (Majumda, 1952,fig 3; Majumda & Saxena, 1961, fig 3; Girgis, 1952b, fig 5,6; Matthes, 1963,pl 5a; Sarbahi, 1939, fig 7; Sehgal, 1965; fig 4)

The antero-lateral aspect of the tissue lining the buccal cavity is, in the region overlying the ventral surface of the palatine bones, formed into two longtitudinal ridges. These ridges may be developed anteriorly as membranous folds. Anterior membranous folds are particularly well developed in Tylognathini. In Tylognathini and in some Labeini, there are lateral lamellae hanging from the longitudinal ridges. In *Osteochilus*, the longitudinal ridges are well developed but the lateral lamellae are present in only a few species (e.g. *O. waandersi*). Histologically, the epithelium of the longtitudinal ridge resembles that of the lamellar but the submucosa contains many striated muscle fibres (Majumdar and Saxena, 1961, fig.4).

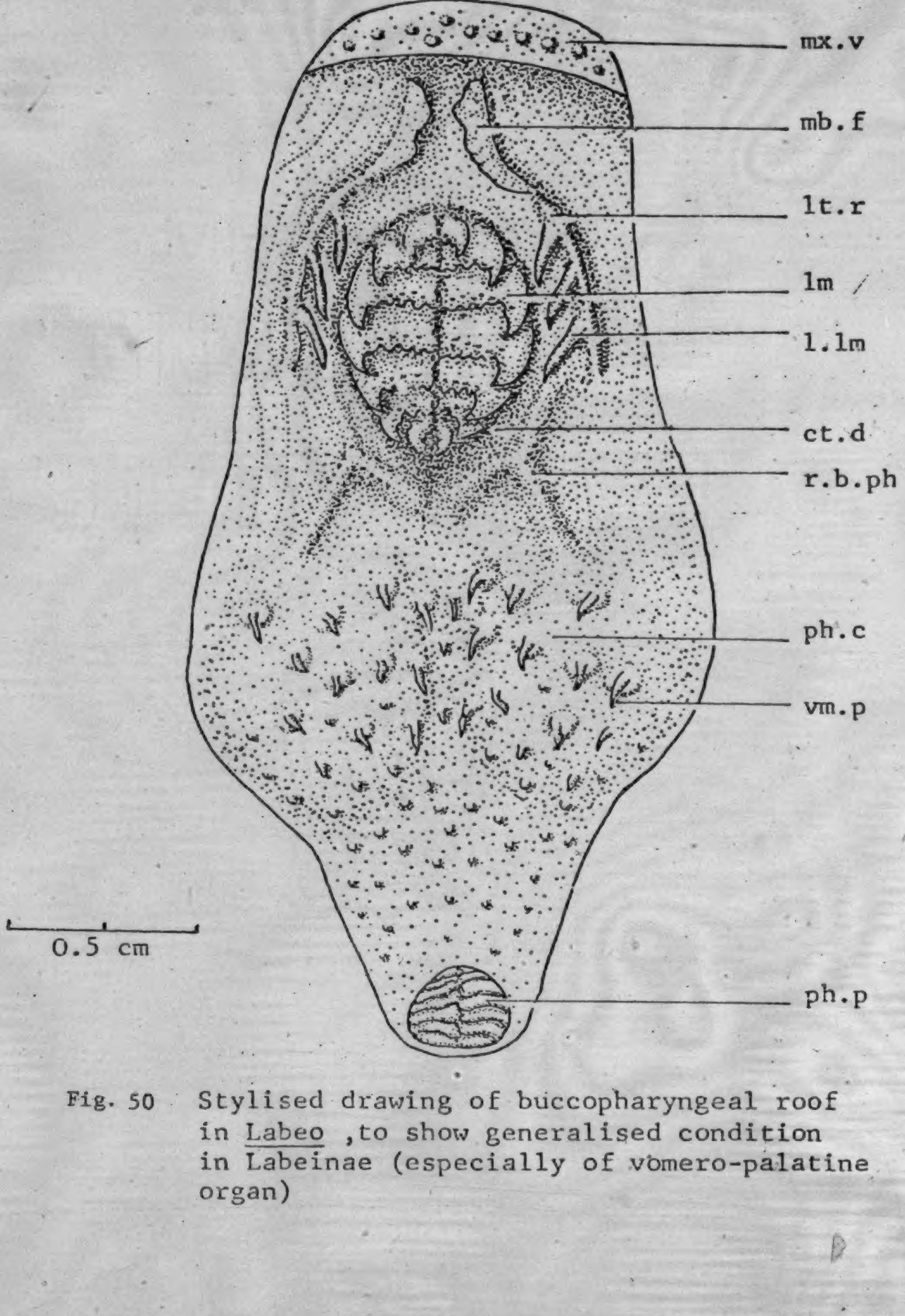

mx.v
mb.f
lt.r
lm
l.lm
ct.d
r.b.ph
ph.c
vm.p
0.5 cm
ph.p

Fig. 50 Stylised drawing of buccopharyngeal roof in Labeo ,to show generalised condition in Labeinae (especially of vomero-palatine organ)

The posterior part of the central depression (which contains the lamellae) forms a raised border between the buccal cavity and the pharynx, but this is not well developed in the mid-line. The raised border is , on each side, formed as a Y-shaped peak, with the tail of the 'Y' pointing anteriorly (fig. 50). Histologically, the epithelium covering the raised border is similar to that of the lateral ridges but taste buds are more numerous (Majumda and Saxena, 1961, fig 4; Moitra and Sinha, 1972).

12. **Dorsal Pharyngeal Cushion** (refer to Fig. 50)

The tissue covering the roof of the anterior pharynx has the overall appearance of a bilobed fleshy cushion. This cushion underlies the ventral surface of the prootic bones (medially) and the exoccipital bones (antero-laterally). The anterior pharynx has numerous papillae scattered over it, these may be globose or vermiform (0.5-1 mm. long). These papillae, the tips of which are directed posteriorly, grade into the smaller, and more numerous globose papillae of the posterior pharynx.

Histologically, papillae epithelium is poor in mucous cells and rich in taste buds compared to elsewhere on the bucco-pharyngeal roof (Girgis, 1952b; fig 8; Majumda, 1952,fig.4, 5; Majumda and saxena, fig 5, 6; Sarbahi, 1939, fig 8; Sehgal, 1965, fig. 5). This high number of taste buds in cyprinids is associated with a hypertrophy of the visceral afferent roots of the glossopharyngeal and vagus nerves (Kappers et al., 1960). Okada & Kubota (1956) have found three distinct types of taste buds in the buccopharynx of *Carassius*. Of these, type III is extremely abundant (1300-2000 per square millimetre) on, and largely restricted to, the pharyngeal cushion. This is in contrast to type II which is found on the sides of the buccopharynx and on the inner surface of opercular, and type I which is widely distributed, but at low density, throughout the buccal cavity.

13. **Pharyngeal Pad Region and Underlying Bones** (refer to fig. 50)

The pharyngeal pad, which is characteristic of cyprinids, is placed dorso-posteriorly in the pharynx. It is a deciduous disc of corrugated, horny tissue (see

Girgis, 1952b, fig. 1) which can be partially calcified in large species of *Barbus* and *Varicorhinus* (Matthes, 1963). Gratzinow (1900)and Horda and Tsukahara (1971:p444,fig. .26) give accounts of the pharyngeal pad histology. The pad is formed largely from cornified epithelium and dense connective tissue which interosculates with dermal papillae. Taste buds sometimes occur beneath (dorsal to) the keratinized layer.The pad underlies the ventral surface of the ovoid masticatory plate of the basioccipital bone. Examination of the cyprinid skeleton reveals that the masticatory plate is an ovoid platform. In Barbinae the ventral surface of this platform slopes dorsoanteriorly at an angle of about 45 degrees to the horizontal basioccipital process. In Labeinae, however, its ventral surface of platform is inclined ventroanteriorly and more or less horizontally to the adjoining basioccipital process. The basioccipital in Barbeinae is also pointed posteriorly but is broadly rounded in Labeinae (fig. 26)

14. Relationship between the pseudobranch and 1st epibranchial bone

Granel (1926,1927) gives a general review of the gross morphology and histology of the teleostean pseudobranch. In Barbinae and Labeinae the paired pseudobranchiae are (in adults) glandular and embedded in the mucosa of the anterolateral portion of the pharynx (see Granel,1927; Matthes,1963). In Tylognathini (but not in Barbinae) the pseudobranch lies a little in advance of a medially directed ossified lamellate process extending from the anterior margin of the first epibranchial bone. In adult Labeinae the glandular pseudobranch lies in a cup shaped hollow formed by a fretted extension of the lamellate epibranchial process.

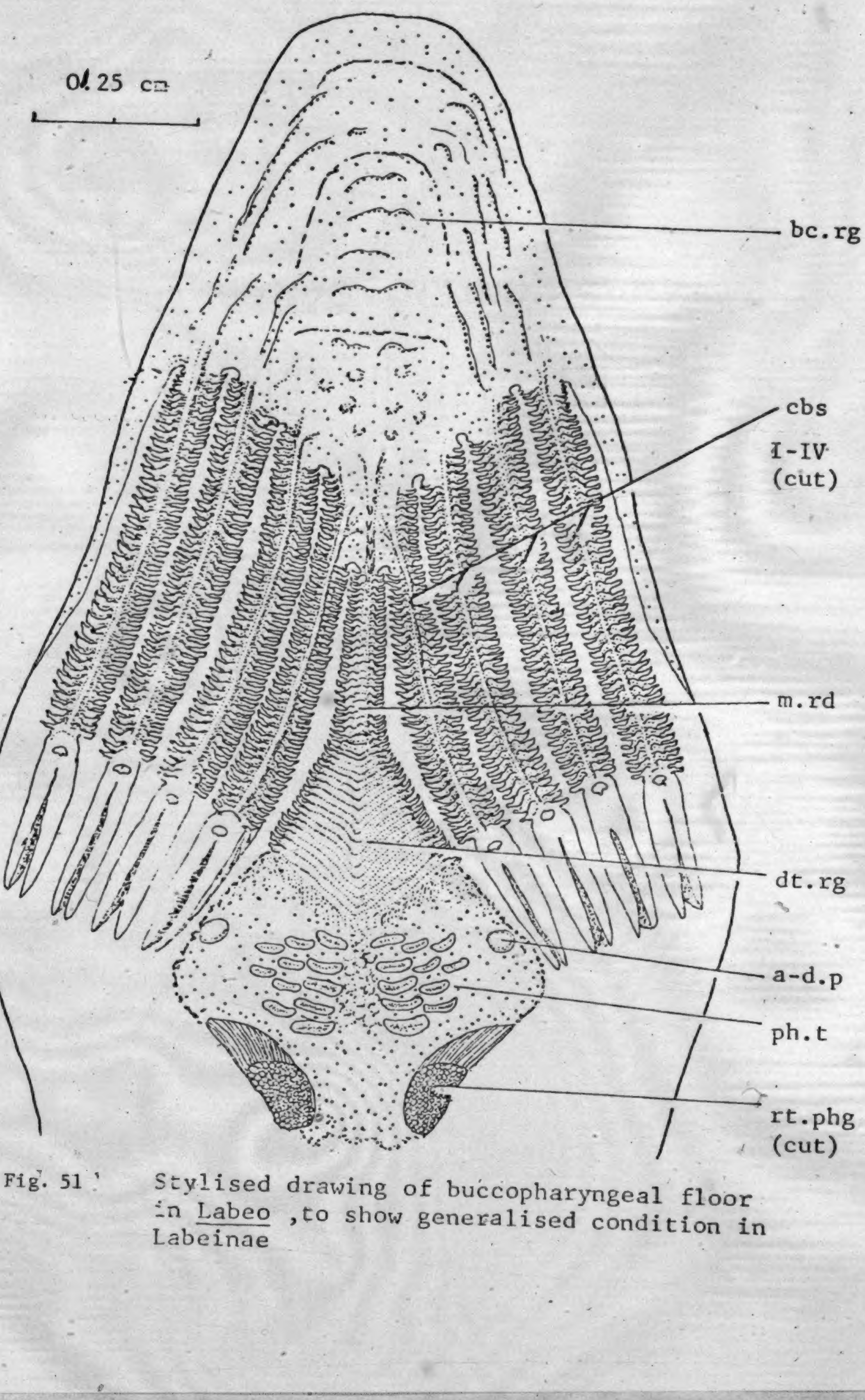
Buccopharyngeal floor (fig. 51)

The gross morphology of buccopharyngeal floor is illustrated in fig. 50, 51 The tissue of the anterior (buccal) region has feeble transverse corrugations and has no distinctive features.

15. **Ventral Pharyngeal Cushion** (refer to Fig. 51)

This structure occurs in both Barbinae and Labeinae, and includes the following elements:

15.1. a median ridge of fleshy tissue extending from the buccal region (overlying the basihyal bone) to a point overlying the antero-ventral process of the pharyngeal bones. According to Girgis (1952a, b) and Bali (1956) this ridge is supported by an unpaired cartilaginous rod.


0.25 cm
bc.rg
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dt.rg
a-d.p
ph.t
rt.phg
(cut)

Fig. 51 Stylised drawing of buccopharyngeal floor in Labeo ,to show generalised condition in Labeinae

15.2 a roughly deltoid area of transverse v-shaped corrugations; the point of each V is directed posteriorly. Histologically, this tissue has a large number of mucous cells and numerous taste buds (Bali, 1956; Girgis, 1952b, 339, fig 9b).

15.3 marginal bony rakers fringing the free edges of the deltoid area. These rakers correspond in number and position with the corrugations. Marginal rakers do not differ histologically or in external appearance from the rakers of the branchial arches (Bali, 1956).

16. **Branchial arches (Ceratobranchials) and gill rakers**

The Barbinae and Labeinae there are five bony branchial arches. Branchial arches 1-4 bear functional gills arches, whereas each ceratobranchial of the fifth arch forms a pharyngeal bone. In Barbinae the gill rakers are, in general, stubby and number fewer than 20 pairs on each gill arch (Reid, 1979). In Labeinae the gill rakers are more numerous and more closely set.

In *Osteochilus* the gill rakers vary between 28-70, in *Labeo* the gill rakers are exceedingly more numerous and in most species show a large numerical increase with increasing standard length. The epidermal layer of the gill rakers contain taste buds and mucous cells (Girgis, 1952b:341; Matthes, 163:14; Kapoor, 1964).

17. **Pharyngeal bones and teeth**

In Barbinae and Labeinae the paired pharyngeal bones lie buried in the mucosa, sub-parallel to ceratobranchial bones 1-4. A description of musculature associated with the cyprinid pharyngeal bones is given by Eastman (1971), Matthes (1963), and Girgis (1952a). The bones differ in shape between Barbinae and Labeinae; they are falciform in Barbinae but triangular and plough shaped in Labeinae (Ramaswami, 1955; Girgis, 1952; Matthes, 1963; and present observation).

In adult Labeinae the dental surface of the pharyngeal bone invariably has three rows of pharyngeal teeth (dental formula 2,4,5-5,4,2). These teeth are, in cyprinids, sequentially replaced several times during life (Evans & Duebler, 1955; Sarbahi, 1939;

Matthes, 1963). In Labeinae, each perfectly formed tooth is obverse and the crown has an occlusal surface in the form of a shallow uncinate spoon (*Cirrhinus* and *Labiobarbus* differ from this general plan in having a notch in the mesial edges of some of the crowns). [3] The teeth are closely grouped together and almost occlude the intervening spaces and crowns, which form a common grinding surface, and they emerge in the posterior pharynx close behind the ventral pharyngeal cushion (fig. 51).

In Barbinae the number of rows of pharyngeal teeth varies from one to three but the majority have three rows and the most common dental formula is 2,3,5–5,3,2 (see also Matthes, 1963; Greenwood & Jobb, 1967). The individual form of these teeth is not constant, and the overall dental pattern may vary both within and between species (Banister, 1973). In Barbinae the crowns are not as crowded as in Labeinae.

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[3] Greenwood, 1972 has refered to *Labeo* fossil pharyngeal bones and teeth from the Pliocene of Egypt).

A FUNCTIONAL INTERPRETATION OF THE OROMANDIBULAR ORGAN

Food and Feeding Habits of Labeinae

A large number of papers deal with this topic, e.g., Matthes, 1963; Kamal, 1964), but they are not very detailed. The following papers are on the food and feeding habits of *Labeo*: Asian: Ahmad, 1967; Sehgal, 1965a; Ahmad &Akhtar, 1967; Chacko &Subramanian, 1949; Das & Moitra, 1963: African: Gauthier - Lievre, 1949, Corbett, 1961; Goorts et al., 1961; Cadwalladr, 1965; Schoonbee, 1969; Kramer; 1973a,b.

The overall view from the literature and also my observations suggest that labeine species are essentially aufwuchs feeders. Aufwuchs is a major dietary component for many barbine species (see Hora, 1940; Fryer, 1959; Matthes, 1963; Jubb, 1966). There is a confusing variety of definitions for aufwuchs in the literature. Aufwuchs is here broadly defined as: a matter complex of algae (the major component), microscopic animals, organic detritus and inorganic items which, in fresh water, forms a slimy covering over the substrata, e.g., rocks, sand, and macrophytes. Especially common in aufwuchs are species of blue green algae (e.g. *Calothrix*), which have their filaments firmly attached to the substratum. According to Fryer (1959), *Calothrix* species are analogous to trees in a woodland community, the bottom is formed by loose filamentous and coccoid algae (Chlorophyceae), diatoms and euglenoids which grow between bunches of *Calothrix* (Fryer, 1959; Bayly & William, 1973).

The microscopic animals which form a part of the aufwuchs are predominantly protozoans, rotifers, and copepod crustaceans (Fryer, 1959; Bayly & Williams, 1973). Crustaceans form up to 40% of the diet of juvenile *Labeo calbasu, L. gonius*, and *L. rohita* but in adult specimens crustaceans (especially copepods) comprise less than 8% of the diet with algae becoming increasingly important, particularly the unicellular forms (Mookerjee, 1945; Das & Mohanty, 1966; Sinha & Moitra, 1915; Poromeswaren et al., 1974). A similar change in dietary pattern has been observed in juvenile *Cirrhinus* (Moitra & Sinha, 1972) and in juvenile *Garra* (Jones, 1941), which suggests that this phenomenon may be general for labeinae species.

Aufwuchs can be categorized by the surface on which it occurs, such as (the terms used in Bayly & Williams, 1973)

i) epipelic - on mud or sand.

ii) epilithic - on rock

iii) epiphytic - on macrophytes.

iv) epizoic - on animal.

The broad microfaunal and microfloral make-up of aufwuchs is similar in freshwaters everywhere (Bayly & Williams, 1973) but particular substrates determine the detailed composition of an aufwuchs community. For instance, the algal component of epipelic and epizoic aufwuchs is least diverse while the microfauna is most diverse (Bayly & Williams, 1973). Organic particles (silt) are always a conspicuous component of aufwuchs even where this is epilithic or epiphytic (Fryer, 1959, and my own observations).

The following functional analysis of oromandbular morphology (which concerns the structures previously described), is made in the light of data discussed above.

1. Rostral Fold, Rostra Flap, and Rhinal Lobe

In Barbinae the rostral fold is rudimentary and serves no obvious function. The down grown rostral fold seen in Labeinae may serve to protect the less robust inner folds of the lip tissue but it is not clear that it does this. In adult Garrini the hypertrophied rostral fold is so down grown that it covers the upper jaw and papillose ventral border has become conterminous with the edge of the upper jaw. Here, the disposition of granuloid papillae on the fold suggests an aufwuchs rasping function, especially where the papillae are heavily keratinized. The fluted inner margin of the rostral fold (seen in *Garra*) suggests a rasping and gripping function. Hora and Mukerji (1936:p143-144) note that rheophilic Asiatic *Garra* and *Crossocheilus* are aufwuchs scrapers. During the course of scraping they accumulate a bolus of aufwuchs behind the ventral margin of the rostral fold. Ingested boli pass through the gut in a bead-like series. Corbett (1961) states that " In its feeding behavior *Garra johnsoni* (Africa) closely resembles *Labeo*, perhaps differing in eating more insects" and Mathes (1963) makes similar observations for *G. congoensis* and *G. dembeensis*. Specimens of *Garra* which I have kept in an aquarium clamp down tightly on hard substrates during the course of feeding and it appears that the ventral margin of the rostral fold forms the anterior rim of the adhesive disc.

Epalzeorhychos are the only Garrini that do not clamp down tightly onto the substrate during feeding, rather they skim over it with the rhinal lobe erect from their sockets. Reid (1979) suggested that erect rhinal lobes could function as hydrodynamic stabilizers, and certainly there is no evidence to suggest that they serve a sensory function.

2. Anterior and Posterior Barbels

It seems probable that the barbels of cyprinids serve as sensory probes when feeding off the substrate. Nevertheless it is remarkable that fishes with apparently closely similar feeding habits differ markedly in the degree of barbel development and, furthermore, it is difficult to believe that the stubby rudiments which represent anterior and posterior barbels in adults of some species can serve a highly developed sensory function. Gosline (1973:p 772) notes that " In *Cyprinus*, lowering of the mandible pulls the lateral end of the maxillary downward and forward, and the maxillary barbel moves with it." Observations in aquarium on Labeinae and Barbinae suggest that this mechanism of barbel protrusion is widespread throughout cyprinids.

The difference in barbel insertion within and between Labeinae and Barbinae may be related to differences in feeding habits, e.g., when *Epalzeorhynchos* feed, the anterior barbels are held forward from the snout and contact the substrate a little in front of the briskly moving fish. I have the impression that the quality of the substrate (including food) is being tested well in advance of the mouth. In cases where fishes clamp down tightly on the substrate (*Labeo, Osteochilus,* and *Garra*) but where forward progress is not brisk, the anterior barbels (where developed) contact the substrate immediately in front of the advancing mouth. On the other hand, *Barbus*, does not clamp down tightly when feeding off the substrate, rather it grubs around within a circumscribed area and moves forward. In this case the anterior barbels contact the substrate on each side of the mouth.

The different lengths of anterior and posterior barbels within and between species of Barbinae and Labeinae may be correlated with the angle the fishes make with the substrate during feeding, e.g. a fish holding its body, head down, at a 45 degree angle to the horizontal can maintain substrate contact with relatively short anterior barbels but requires relatively long posterior barbels (as in the majority of *Osteochilus*). Obviously rheophilic aufwuchs scrapers (e.g. *Garra*) must, for hydrodynamical reasons, remain relatively flush with the substrate during feeding and in this case there may be a compensatory increase in anterior barbel length and a corresponding decrease in posterior barbel length.

3. Upper Labial Fold

This is divided only in adults of *Osteochilus* and *Labeo*. The outer palisade of papillae appears, from the concentrated presence of taste buds, to be sensory whereas the lightly keratinized costae of the inner surface apparently serve a scraping and gripping function. It is likely that, where they are developed, costae are of use in allowing the fish to adhere to boulders in swift water (*Osteochilus vittatus* group, *O. waandersi* group, and *O. triporus* group). Rheophelic *Labeo* have finely crenulated costae which may improve the gripping action. In the *Osteochilus hasselti* and *O. melanopleura* groups, which live in slow moving or still water habitats, the costae are reduced to a round mound shape. Apart from the adhesive properties of costae it seems probable that they are also adaptive for scrapping up epilithic aufwuchs. I have the impression that the more microphytophagous (and rheophilic) the species, the more finely crenulated are the costae (see also the comment by Matthes, 1963: p11). However, this notion is not based on any detailed dietary analysis. There is some evidence that algal filaments in rapid water are more robust (Macann, 1974) and therefore, they may be more resistant to scraping.

It is probable that gripping and scraping is, in life, passive, i.e. dependent on the overall movement of the fish or on jaw protrusion. The upper labial fold does not appear to be prehensile and there is no active muscle present (Howes, personal comment).

4. Upper Jaw and Callus Sheath

Gosline (1973) states that : "The cypriniform variations in jaw structure appear to represent adaptations for feeding ...." This fact cannot be denied. The absence of premaxillary teeth in cyprinids is, according to Gosline (1973) associated with the "pipette system" of feeding common to this group, but it is not clear that this is a valid correlation. In cyprinids the premaxillae are protusible (Fiebiger, 1931; Girgis, 1952a; Matthes, 1963; Alexander, 1966,1967; Datta Munshi & Singh, 1966; Ballintijn et al.,1972; Gosline, 1973; Vandewalle, 1975). In labeine species the premaxillae are rendered particularly mobile by an elongated medial extension of the ethmoid bone and its linkage with the kinethmoid (rostral). According to Girgis (1952a:p314):

> "Protrusion of the mouth (in *Labeo*) takes place by the contraction of the geniohyoideus (=protactor hyoideii) and sternohyoideus muscles. The kinethmoid bone and sigmoid ligament allow, but finally check, the movement".

Alexander (1966) and Gosline (1973) consider opening of the mouth and protrusion of the jaw to be largely independent processes. They think that protrusion of the premaxillae can be useful in getting the mouth opening close to the food that is to be sucked in (by negative pressure in the expanded oromandibular cavity) when the body is at an angle to the substrate.

5. Maxillary Valve

The main function of the maxillary valve is evidently in preventing reflux of the respiratory stream during expiration (Mitchell, 1904; Kapoor, 1956; Das & Subra, 1964).

Nevertheless, an accessory, sensory function is suggested by the presence of taste buds in the soft globose papillae present on the outer face of the valve.

6. Mouth Opening

The position of the mouth opening provides a crude indication of the degree to which a fish is associated with the substrate when feeding. In those groups which are feeding above (midwater) as well as on the substrate the mouth is terminal or subterminal. In specialized Labeinae which are aufwuchs feeders, where a close contact is maintained with the substrate, the mouth is conspicuously ventral.

7. Lower Jaw and Callus Sheath and Its Relationship to the Upper Jaw and Callus Sheath

Normally the lower jaw probably serves as a crude scraping device in both Barbinae and Labeinae. In all Labeinae there is a keratinized cutting edge at the lower jaw. In *Tylognathus, Barbichthys* and Barbinae the horny cutting edge to the lower jaw is not matched by a corresponding callus sheath to the upper jaw, and they are apparently used for shovelling aufwuchs off hard surfaces (e.g. see Matthes, 1963:p19,23). Specimens of *Tylognathus,* which I have kept in an aquarium, appear to use the mouth rather like a bulldozer shovel when feeding off epilithic aufwuchs. It appears that a shovelling action effectively detaches even firmly attached algae, (e.g., Fryer (1959), examined 43 specimens of *Varicorhinus nyasensis* and found that their guts contained mainly *Calothrix*, plus fragments of macrophytes and arthropods).

In *Cirrhinus, Labiobarbus,* Labeini, and Garrini the cutting edge of the lower jaw is matched by a keratinized edge of the upper jaw. This arrangement suggests that during feeding a clipping rather than shovelling action is involved. With reference to the epilithic aufwuchs scraper *Labeo cylindricus,* Fryer (1959) considers that if the opposing callus sheaths made close contact with the rock during feeding there would be a high percentage of *Calothrix* (filamentous algae) in the gut. In fact, Fryer (1959:p189) found that in 64 specimens of *L. cylindricus* examined (12–34 cm SL) the gut contents were almost entirely composed of loose aufwuchs and such fine detritus as tends to accumulate on rocks. Some guts did contain a small amount of *Calothrix* but most contained only loose aufwuchs and detritus (I have observed the same thing in the majority of *Osteochilus*). I think it probable that much of this loose material is detached by the scraping action of the lip costae (see under 3 and 8) and then sucked into the mouth by expansion of the oro-branchial chamber (see under 4). The precise advantage of the clipping action is perhaps that it is effective in chopping up the algal mat. Matthes (1963) claims that some species of aufwuchs scraping *Labeo* (e.g. *L. variegatus*) select diatoms out from between algal filaments during feeding, but he does not indicate how this fact was ascertained.

8. Lower Labial Fold and Its Relation to Upper Labial Fold

The coarse truncated papillae on the lower labial fold in *Tylognathus* suggest a crude scraping function. Hora & Mukerji (1936) note that *Labeo dero* (=*Tylognathus dero*) feed by stone "licking" and that during feeding the lip is probably reflexed back thus placing "spinate papillae" in close contact with the rock. This scraping function may be refined in *Osteochilus* and *Labeo* by the development of keratinized costae which are finely crenulate; apart from improving scraping function, they may be of use for adhering to boulders in swift current. The median bunch of trilobed papillae seen in the lower larbial fold of *Osteochilus* and *Labeo* species suggests a sensory function. In some *Osteochilus* species, however, these papillae are lightly keratinized.

The upper, and the lower labial folds in rheophilic, aufwuch scrapers (e.g. *Labeo forskalii*, and *Osteochilus enneaporus* etc.) are often grossly hypertrophied and sucker-like. Lotic or lentic, epipelic aufwuchs browsers (e.g. *Labeo senegalensis*, and *Osteochilus hasselti* etc) have relatively smaller and thinner labial folds.

9. Post-mandibular Region

The lateral hollows (lacunae) as well as housing the base to the posterior barbels provide space for the accommodation of the posteroventral borders of the retracted premaxillary and maxillary bones. In Labeini, the post-labial development of the medially lacunar extensions partially dissociates or separates the lower labial fold from the gular region. In *Labeo* a transverse sulcus (formed when lacunar extensions meet in the mid-line) results in a relatively deep disjunction between the lower labial folds forming, together with the upper labial fold, a discrete, sucker-like fleshy ring. The completeness of the sealing edge may improve the adhesive properties of the labial fold - a property possibly enhanced, in rheophilic species, by the regression of the outer palisade of conical papillae on the upper labial fold as well as the median bunch of tri-lobe papillae on the lower labial fold. In cases where the transverse sulcus is deeply incised (e.g. in *L. coubie*) the mouth is apparently rendered particularly protrusible and mobile; considerable alterations in body/substrate angle can be effected without detaching the sucker from the substrate.

10. **Buccopharynx in general**

The researches of several authors(Sarbahi, 1939; Al Hussaini, 1949 ; Majumdar, 1952; Majumdar & Saxena, 1961; Girgis, 1952a) indicate that the buccopharynx in adult cyprinids is distinguishable into the following:

i). a mucus secreting buccal region (mucus cells comprise 80% of the entire buccal coat in *Labeo rohita* according to Sabarhi, 1939,p.100) with a few scattered taste buds (in Labeinae they are concentrated on epithelial ridges, especially on the raised border of the pharynx).

ii). a dorsal pharyngeal cushion which apparently secretes less mucus than the buccal region, but is rich in gustatory cells, especially on the papillae.

The morpho-plan of a mucus secreting buccal region and a gustatory pharyngeal region is a generalized character for teleosts (e.g. see Kapoor&Evans, 1975) and, in cyprinids at least, this is consistent with the idea of anterior bolus-formation coupled with a posterior taste and sorting system. Dorier&Bellon(1951/52) consider that one main function of the dorsal pharyngeal cushion is gustatory(see also Hara, 1971 and Vasilevskaya&Pavlov, 1971): peristaltic movement of the dorsal pharyngeal cushion also apparently aids in deglutition (Girgis, 1952a). Jara (1957,1963) and Matthes (1963) have proposed a hypothesis that the dorsal and ventral pharyngeal cushions act together as a press in preventing inflow of water to the gut.

11. Vomero-palatine organ and associated structure

There are three hypotheses associated with functions of this organ:

i). The **Respiratory hypothesis** of Majumdar(1952) and Majumdar&Saxena(1961) suggests that the vomero-palatine organ, in conjunction with the papillae of the dorsal pharyngeal cushion, provides an accessory respiratory surface. In order to test this hypothesis these authors conducted a series of respiratory experiments which, in my view, were ill conceived. The results obtained from these experiments do not support the respiratory hypothesis. The only acceptable evidence for a respiratory function would be a demonstrated increase in physiological oxygen concentration in the blood of the efferent (as compared to the afferent) capillaries of both lamella and papillae. To the best of my knowledge experiments designed to test for such an increase have not yet been conducted. It is not, therefore, possible at present to confirm or deny the respiratory hypothesis. One point suggestive of a respiratory function is that the vomero-palatine organ is greatly regressed in adults of labeine species which live in torrential and presumably oxygen rich streams. It should be noted, however, that there is no histological evidence to show that lamellae or papillae are more richly vascularized than the rest of the tissue roofing the buccopharynx.

ii). The **Sensory hypothesis** of Girgis(1952a) states that "The position and shape of the lamellar organ of the palate suggest some specialized sensory function". Nevertheless, Girgis finds the nerve endings in lamellar epithelium to be similar to those in adjacent tissue and from this he concludes that a specialized sensory function is, after all, improbable. Al Hussaini (1949) has described paired "palatine cushions" found in *Gobio* just posterior to the maxillary valve. He reports an experiment where gravel particles sucked in with the respiratory current are immediately rejected as soon as they touch the 'palatine cushions'. It does not seem that the 'palatine cushions' of *Gobio* are homologous with the vomero-palatine organ, nevertheless, it may be that there is some functional correspondence between these structures.

iii). The **Trophic hypothesis** of Matthes(1963) states that "The regular form of the (*Labeo*) vomero-palatine organ suggests some specialized function in relation to feeding, however, no voluntary muscle being present, any active function is excluded". Matthes further suggests that the precise function might be in 'passively mixing' small food particles (e.g. algal cells and fragments) with mucus (see also comments in Kapoor et. al., 1975; Kapoor&Evans, 1975). Matthes does not, however, clearly formulate this hypothesis and it is difficult to be exactly sure of what he means. Reid(1978) states that striated muscle fibres are present in a longitudinal arrangement in the cyprinid buccopharyngeal mucosa and these fibres are probably responsible for the systematic movements which have been observed passing over the buccopharyngeal roof in freshly killed fishes (Majumdar, 1952; see also Jara, 1957; 1963; King, 1975). Lateral ridges, especially when developed anteriorly as membranous folds, are particularly rich in striated muscle fibres (see also Sarbahi, 1939).

Reid's hypothesis is (developed and restated from Matthes's original idea) that the vomero-palatine organ is concerned in bolus-formation by the active co-mixing of precipitated mucus secretions with ingested particles (food and sediment). Reid gives the following observations to support the general notion that the vomero-palatine organ serves a trophic function, which agree with my observations:

a. all cyprinids which have the organ are essentially microphagous. Nevertheless, the particular size of the particles which they ingest varies.

b. epipelic aufwuchs browsers usually have well developed vomero-palatine organs (e.g. *Labeo niloticus, Cirrhinus sp.*). The size of silt particle ingested on medium fine to course substrates is in the region of 0.125-1.0 mm. An exception to this generalization (a case where the vomero-palatine organ is poorly developed) is found in *Labeo rohita* which probably ingests particles slightly coarser than those taken by other epipelic browsers (according to Das & Moitra, 1963, up to 11% of the diet of adult *L. rohita* is made up of small benthonic crustaceans).

c. in epilithic aufwuchs scrapers the vomero-palatine organ is, in the adult, present in a relatively regressed condition. The impression from general oromandbular morphology and from limited ecological data is that torrenticolous aufwuchs scrapers (e.g., *Labeo sorex*, and many *Garra* species) are more microphagous than labeine species which occur in less turbulent habitats (see also Matthes, 1963,p.11) . It is interesting, therefore, that adult specimens of torrenticolous labeine species invariably have a severely regressed vomero-palatine organ whereas fishes from less turbulent and less trophically restricted habitats do not usually show severe regression of the organ.

It appears that the maximum development of the vomero-palatine organ is seen in fishes whose particle intake is neither too large nor too small.

Osteochilus are microphagous and the majority are epilitic aufwuchs scrapers living in turbulant habitats; the vomero-palatine organ is completely regressed in this genus. In some species, longitudinal ridges and lateral papillae are developed but in varying degrees (e.g., *Osteochilus microcephalus*, *O. waandersi*, and *O. ingeri*).

12. **Pharyngeal mill**

It is evident that the (dorsal) pharyngeal pad supported by the mastigatory plate of the basioccipital bone provides a horny surface in opposition to the grinding surface formed by the (ventral) pharyngeal teeth. According to Gratzionow(1900) the dermal papillae which are in contact with the pharyngeal pad serve to secure it in place during the milling process. Hoda and Tsukahara(1971,p.491-492) state: "An interesting fact revealed in this study (of *Cyprinus*) is the finding of taste buds on the horny pad -thus the pad may be considered not only masticatory but to a certain extent gustatory too". (see also Gratzionow, 1900 who was surprised to find taste buds in the pharyngeal pad of the goldfish).

The functional significance of the number of pharyngeal tooth rows in cyprinids remains a mystery. Greenwood & Jubb(1967) have pointed out that both barbine and leusciscine genera are trophically varied yet the former group usually has triserial tooth rows whereas the latter usually has biserial rows. By comparison it does not seem that the labeine genera which invariably have triserial rows, are as trophically diverse as barbine genera. For example, Matthes(1963,p3) finds that *Barbus:* "show a range of variation in feeding habits which appears out of proportion to the relatively minor differences in morphological features related to feeding.--One corollary of this is that its members are characteristically 'facultative feeders', i.e. the species may have a very distinct preferential diet under normal circumstances, but should these change, readily adapt to another, which may be very different". A possible case in *Barbus* of trophically determined intraspecific ecophenotypic variation in pharyngeal bones and teeth has been discussed by Banister(1973) and a similar case in *Microgrex* has been discussed by Goren et.al.(1973).

The fact that the pharyngeal bones and teeth are remarkably uniform throughout the Labeinae suggests that their grinding function is essentially similar. I have the impression from the form and arrangement of the pharyngeal bone and teeth in relation to the form and angle of inclination of the mastigatory plate, that in Labeinae the pharyngeal grinding action is directed relatively dorsally. Girgis(1952a) suggests that *Labeo* "differs (from other cyprinids) in the fact that the two sets of teeth work only against the horny pad and not against each other". Assuming this to be true then it is likely that a transmitted grinding force would place the basioccipital process in mechanical upthrust against the anterior vertebrae (Weberian apparatus) -the dorsal aorta being sandwiched between them. In Labeinae the basioccipital process is terete and the channel for the dorsal aorta is at least partially roofed over by bone. These are interpreted as devices which protect the dorsal aorta from being pinched when the pharyngeal mill is in operation.

In Labeinae alone the neural complex of the Weberian apparatus makes direct contact with the supraoccipital process (in other cyprinids this connection is normally affected by a ligamentous sheet Howes, 1978). This development renders the Weberian apparatus more rigid and stable in the face of mechanical upthrust. The upthrust action of the pharyngeal mill might also tend to squash the pseudobranchs and this may be why these are, on each side, enclosed by a bony extension from the first epibranchial bone.

13. Gill rakers

Several authors suggest that in teleosts the array of gill rakers covering the anterior face of the branchial basket acts as a sieve for ingested particles–food and sediments –thereby shielding the gill lamellae (Girgis, 1952a; Kapoor, 1964; Frank, 1965). Certainly in preserved specimens of labeine species it is not unusual to find that the entire anterior face of the branchial basket is covered with particles of silt intermingled with mucus and particulate organic matter.

Svardson (1970) found that in coregonid species the gill raker number is positively correlated with increasing percentages of benthic food eaten and that the spacing of the rakers is associated with the size of ingested particles. Frank (1965) finds gill raker count to be highest in microphagous Ostariophysi (see also Kapoor, 1964). The high number of closely spaced gill rakers seen in Labeinae correlates with the fact that they are , in general, more microphagous and benthically restricted than Barbinae. In *Osteochilus waandersi* and *O. enneaporos*, apparently specialized epilithic aufwuchs scrapers , the gill raker count is remarkably high.

In labeine species the gill rakers usually increase in number with increasing standard length and this presumably maintains the mesh size of the sieve. The precise number of gill rakers (for a size class) can differ markedly between sympatric siblings (e.g. *Osteochilus triporus* and *O. intermedius*; *Labeo niloticus* and *L. horie*); this presumably reflects an interspecific dietary partition. Kafuku (1958) found that among "local races" of *Carassius* those with longer intestines have higher gill raker counts. It would be interesting to see if this correlation holds true in labeine species.

A PHYLETIC INTERPRETATION OF OROMANDIBULAR MORPHOLOGY

Matthes (1963) considers that the primitive cyprinoid feeding habit is "fundamentally predaceous" , while Gosline (1973) suggests that "the cypriniform ancestor may have been a (small mouthed, weakly toothed) bottom feeding form--- that ate primarily small benthic organisms.", Howes (1978): states that "I take the contrary view to these authors (Gosline & Matthes) and maintain that it is the omnivores of the respective cyprinid lineages which represent the primitive type.".

An omnivore is nutritionally more generalised than either a herbivore or a carnivore and in this respect I agree with Howes (1978). Nevertheless, I consider that, in the present context, terms such as 'herbivore', 'carnivore' and 'omnivore,' are of limited application because:

i) there is in my opinion no rigorous dietary analyses currently available for any cyprinids in nature.

ii) there are more aspects to diet than broad categories of food ingested.

iii) in a phylogeny, the diet of an ancestor can only be inferred from the trophic morphology of recent forms. Labeinae, for example, can be broadly categorized as aufwuchs feeders.

Algae are a major constituent of aufwuchs and in this sense labeine species might be regarded as herbivores (see Girgis, 1952a). Nevertheless, as indicated previously, aufwuchs is not simply an algal slime but rather a complex community with both plant and animal components. In the case of Labeinae, at least, I consider that, be it plant or animal, the nature of food material (e.g. particle size, shape, texture, digestibility) is a factor of prime importance when discussing trophic evolution (see also Moriarty et al., 1973).

In Labeinae the ontogenetic shift from a diet rich in micro-crustacea to one with an increased bulk of algal material could be regarded as evidence for a phyletic changeover from carnivore to herbivore or from food of one form to food of another form - or both. However, because such arguments, as presently formulated, are not based on morphological homologies, it is difficult to see how they could be tested.

1. **Rostral lobe, rostral flab, rhinal lobe**

The presence of a rudimentary rostral fold is widespread throughout the cyprinids. In Labeinae the fold is downgrown and I consider this condition to be derived. A relatively downgrown rostral fold is seen in some Barbinae (*Prolabeo,* and *Aldeichthys*) but, from the distribution of other characters, this is interpreted as a parallelism. *Labeo* is unique in having a rostral flap. This clearly is a phyletic derivative of the rostral fold, evolved to accommodate an expansion of the upper and lower labial fold – certainly it forms in this way during early ontogeny. In both Labeini and Garrini the ventral margin of the fold is indented but the pattern of indentation varies. The irregular margin pattern in Labeinae (especially in *Labeo*) is apparently a phyletic regression from the down grown pattern (seen in Garrini) congruent with the reflux of the rostral flap. The granuloid papillae which form a ventral border to the outer face of the rostral fold (especially in *Garra*) are unique to Garrini. In *Semilabeo* the keratinized studs which cover most of the anterior face of the rostral fold have, it seems, evolved from granuloid papillae.

A rhinal lobe is on each side of the anterolateral aspect of the snout in *Epalzeorhynchos*. Rhinal lobes when erected from their sockets apparently have a specialized hydrodynamic role (Reid 1979). I interpret the loboid region seen on each side of the tip of the snout in *Crossocheilus* (see Alfred,1971) as a primitive precursor to the rhinal lobe condition.

2. **Anterior and posterior barbels**

Gosline(1973) considers that the occurrence of barbels "in two or more groups may merely represent an inherent cypriniform ability to develop the character under certain conditions rather than a close relationship between fishes bearing the feature". Myer(1960) considers the presence or absence of barbels to be a character of little importance in discussions of cyprinid relationships and Gilbert and Bailey(1972) have expressed a similar view in an extensive discussion entitled "barbels and their significance in the classification of Cyprinidae". Most of Gilbert and Bailey's discussion revolves around the concept of " a generic level character" and problems of "weighting" this character. Smith(1945), judging from his key, apparently assumed that barbels are of no value as indicative of systematic relationship and he recognized many labeinae genera with species showing more than one arrangement of barbels (e.g., according to Smith *Osteochilus* may have two pairs of barbels, only anterio barbels, or only posterior barbels). However, I believe that those labeine species listed by Smith as having different sets of barbels are not congeneric (or that the barbels had been overlooked by Smith). Although the position and numbers of barbels may have little significance for the taxonomy of most cyprinids, I do not think that the reservations of Gilbert and Bailey apply to the Labeinae; since the distribution of barbels in this group is quite stable at the generic level. There are exceptions in large and wide-spread genera such as *Labeo* and *Cirrhinus* which exhibit a wide variation of barbel arrangement, but they can be explained in the evolutionary sense.

Out-group comparisons indicate that the presence of two pairs of barbels is primitive for both Barbinae and Labeinae (at least in species from both of these taxa the anterior pair and to a lesser extent the posterior pair may regress during ontogeny and are sometimes lost altogether). The evolution of Labeinae, it seems, involved a similar process of regression and lost of the barbels. It is evident from the distribution of other oromandbular characters that regression and loss of barbels has occurred independently in Tylognathini, Labeini, and Garrini.

From out-group comparisons it is clear that the primitive position for the anterior barbels is sub-rostral (as in Barbinae). The antero-rostral barbels of Labeinae are evidently derived from the sub-rostral condition. Latero-rostral and antero-rhinal barbels (*Labeo*) apparently represent, in order of increasing apomorphy, a morphocline from the antero-rostral condition. An example of these is seen in many *Labeo* species complexes (Reid, 1978).

From out-group comparisons it is evident that the primitive condition for posterior barbels is for them to be exposed on each side of the head. In *Labeo* and *Osteochilus* the posterior barbels are at least partially hidden within a more or less cavernous post-labial lateral groove and this condition is synapomorphic (Reid, 1978 and my observations). In Garrini the incorporation of posterior barbels in the ventral postero-lateral margin of the downgrown rostral fold appears to be a uniquely derived feature.

3. Upper labial fold

The upper labial fold is a derived feature which unites Labeinae. It is not seen in Barbinae (except as a parallelism in *Prolabeo*) and is less developed in Tylognathini. In Garrini the upper labial fold is always rudimentary and it regresses during ontogeny (concomitant with a downgrowth and hypertrophy of the rostral fold) whereas in Labeini the fold may be papilated at the rim and have outer and inner regions. Clearly this latter condition is advanced. In *Osteochilus* and *Labeo* the outer region is primitively comprised of a palisade of relatively conical papillae while the inner region is formed as a costate surface. The crenulations, seen only on the costae of *Labeo* are presumably derived from a simple condition similar to that seen in *Osteochilus*.

The evolution of costae on the upper labial fold in *Osteochilus* can be expressed in two lines, in order of increasing apomorphy, as a morphocline: i) in the *O. waandersi* group, adapted for mountain stream habitat, the costae are enlarged and increased in number. ii) in the *O. hasselti* and *O. melanopleura* group, the costae are reduced to a short, round, mound-shaped structure adapted for the less turbulent habitat.

4. Upper jaw and callus sheath

According to Matthes(1963), "*Varicorhinus* appears most closely related to *Barbus*, though it shares some features with *Labeo* and especially with *Garra*. Only further research can determine whether characters like, for instance, the absence of premaxillary pedicels, are indicative of any direct relationship with the latter two genera, or only secondarily and independently acquired, as is probably the case". This idea of Matthes can be restated in two questions: i) Is *Varicorhinus* more closely related to *Barbus* than it is to *Labeo* or *Garra*, and ii) Is *Labeo* more closely related to *Garra* than it is to *Varicorhinus*?

To discuss question one is beyond the scope of this study but, in my opinion, the answer to question two is in the affirmative. I noted in an out-group comparison that the absence or severe reduction of premaxillary pedicels is a derived character acquired in Barbinae and Labeinae. Therefore, on the basis of this character, *Varicorhinus* cannot be included in Labeinae, unlike *Labeo* and *Garra* which share uniquely labeine features.

The corium of the upper jaw is usually fleshy in Barbinae and Tylognathini but not in Labeini or Garrini - in which taxa there is a callus sheath over the corium. I believe that the callus sheath is a derived character which unites Garrini and Labeini.

5. **Maxillary valve**

The presence of the maxillary valve is a shared primitive character for Barbinae and Labeinae. The slight variation in the form of this valve within and between these taxa is not phyletically significant in the present context (see Mitchell, 1904; Saxena, D., 1959, oral valve in *Labeo rohita*; Das & Subla, 1964, oral valve in *L. diplostomus* (=*Tylognathus diplostomus*).

Mitchell (1904) notes that many cyprinids lack a mandibular valve and it is absent in most Barbinae and Labeinae. There is a mandibular valve in *Barillius* (Rasborinae) and in the labeine genus *Barbichthys*. I do not have sufficient data on the distribution of the mandibular valve among other cyprinid taxa to fully discuss the phyletic significance of this structure.

6. **Mouth opening**

The ventral (inferior) mouth opening of Labeinae is apparently derived from a sub-terminal condition similar to that seen in Barbinae. During early ontogeny there is, in labeine genera, a shift of the mouth opening from a sub-terminal to a ventral position. In the derived form of *Osteochilus* the mouth position is secondary changing back to a terminal position in the *O. melanopleura* group.

7. Lower jaw and callus sheath

The club-like dentary bone (with its anteriorly situated coronoid process) of *Labeo, Osteochilus*, and *Lobocheilus* has, it appears, evolved from a condition similar to the hook-shaped dentary seen in Barbinae and Tylognathini. *Cirrhinus* and *Labiobarbus* (Labeinae) have a median fleshy prominence which follows the contours of the underlying dentary symphysis. The presence of a prominence in both of these genera is apparently a synapomorphy. *Barbichthys* has a similar fleshy mental process, which suggests that it may be related to *Cirrhinus* and *Labeobarbus*. A club-like pre-coronoid arm to the dentary is also seen in *Varicorhinus* (Barbinae) but from the distribution of other characters this is a parallelism. The corium to the lower jaw is not hypertrophied in Labeinae in contrast to the condition in many Barbinae.

A callus layer of keratin on the edge of the lower jaw is a character that is widespread throughout the Cyprinidae and it occurs in some Barbinae (e.g. *Barbus* and *Varicorhinus*) and in most Labeinae. It may well be that this 'sector mouth' condition is apomorphic for higher cyprinids which would include Barbinae and Labeinae. Certainly, on present evidence, it would be unwise to conclude that the presence of a sector mouth in species of Barninae and Labeinae is the result of a parallelism.

8. Lower labial fold

A lower labial fold is a derived character uniting Labeini and Garrini with Tylognathini. This structure is not seen in Barbinae. In Tylognathini and Garrini the lower labial fold is rudimentary and in the latter tribe the lower fold (like the upper fold) regresses during ontogeny concomitant with a downgrowth of the rostral fold and in *Garra* and *Semilabeo* there is an elaboration of gular region tissue. I suggest that the cirrhinine condition is primitive and that the garrine condition -being a secondary regression from the primitive state- is derived. It is pertinent at this point to quote Hora(1921,p.643): "In almost all the (Garra) species that occur in Persia, Syria, and Africa the mental disc is less specialized and the true lips are usually present."

In Labeinae, by contrast, the lower labial fold may be hypertrophied (especially in *Osteochilus, Labeo,* and *Lobocheilus*) and may have an outer and inner region (*Osteochilus* and *Labeo*) and this is probabl[illegible]n advanced condition. The median cluster of trilobed papillae which comprises the outer region, is a feature unique to *Osteochilus* and *Labeo*. The rudimentary trilobed papillae which occur in some species of African *Labeo* is apparently a secondary regression of the well developed form seen in *Osteochilus* and in certain Asiatic *Labeo* (Reid,1978).

9. Post mandibular region

In Tylognathini and Garrini and in most Labeini the lower labial fold interosculates with the anterior gular region. In *Labeo*, alone, this connection is fully interrupted by transverse post-labial sulcus. I consider this arrangement to be a derived condition.

10. Vomero-palatine organ

All cyprinid taxa sharing a vomero-palatine organ seem to constitute a monophylitic assemblage. All cyprinids considered to be labeine on other oromandbular characters have (at least in early ontogeny) a conspicuous vomero-palatine organ of essentially the same shape and histological structure and occurring in the same position. It is interesting to note that *Oreodaimon* (Africa) does not have a vomero-palatine organ and this fact strengthens Greenwood & Jubb's(1967) argument that *Oreodaimon* is not congeneric with *Labeo*. Matthes(1963,p.19) states that *Garra* ... "seems closest to *Varicorhinus*" and further (p.31) "Even though a genus like *Garra* shows a number of *Labeo*-like characters, these are probably only due to convergent evolution and its closest affinities are quite definitely with fishes of the *Barbus* group."I disagree. The presence of a vomero-palatine organ in *Garra* is, in my opinion, strong evidence that this genus has a labeine pedigree.

Because of insufficient data there is some difficulty in making a phyletic interpretation of the elements which comprise the vomero-palatine organ. In Labeinae the number of perfectly formed lamellar pairs is commonly seven (varies from 5-9);

examples of genera with seven pairs are *Cirrhinus, Labeo,* and *Crossocheilus* which suggests that this number may be a plesiomorphic labeine condition. In *Tylognathus*, and *Barbichthys*, however, there are four or five lamellar pairs and individual lamella are rather smooth. It might be argued, on the principle of parsimony, that this lower number is ancestral to the seven(5-9) arrangement. On the other hand one might think that the incrassate nature of *Tylognathus* and *Barbichthys* lamellae is derived.

In rheophilic aufwuchs scraping Labeinae, the vomero-palatine organ is usually rudimentary in adults, and Matthes(1963) considers that this represents a primitive condition. I do not share this view. It has been argued above that the degree of development of the vomero-palatine organ is associated with the size of ingested particles (food and sediment). Rheophilic aufwuchs scrapers apparently ingest very fine particles and this fact correlates with a regression of the vomero-palatine organ during ontogeny. From the above ontogenetic and ecological data, I argue that the relatively simple vomero-palatine organ seen in these otherwise highly specialized rheophilic fishes does not represent the primitive labeine condition. On the contrary, a regressed vomero-palatine organ is a derived condition which, arguing from the distribution of other oromandbular characters, has evolved independently within both Labeinae (*Osteochilus, L. coubie,* and *L. forskalii*) and Garrini (*Garra* and *Semilabeo*).

11. Pharyngeal pad region

There are no pharyngeal tooth plates in cyprinids; instead pharyngeal teeth act against the pharyngeal roof - a feature unique to this group (Nelson, 1969;p.493). The discrete ovoid mastigatory platform which characterizes the pharyngeal roof in Labeinae has apparently evolved from a condition similar to the 'sloping platform' common to most other cyprinid taxa including Barbinae. The discrete platform of Labeinae occurs in conjunction with a terete basioccipital process [4] which is apparently derived from a structure like the scute basioccipital process which occurs in most other cyprinids (e.g. see Miakowski(1960) who figures the basioccipital process and mastigatory plate for thirteen species of European cyprinids; see also Soresco, 1971). The thickening (by ossification) of the lateral borders of the dorsal aortal channel on the basioccipital process is a specialized feature of Labeinae. A derivative of this condition is seen in *Labeo* where the fretwork of bone at least partially roofs over the canal for the dorsal aorta – thus extending posteriorly the dorsal aortal canal of the basioccipital bone.[5]

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[4] This condition is approched in *Catla* see Saxena&Khanna, 1965.

12. Relationship between the pseudobranch and the 1st epibranchial bone

Free plumed pseudobranchiae is the primitive teleostean condition according to Granel(1927), but on the basis of an out-group comparison, I consider glandular pseudobranchiae embedded in the mucosa to be primitive for both Labeinae and Barbinae . The association of each pseudobranch with a lamellate process of the first epibranchial bone is, however, a uniquely labeine development. In adult Labeini each glandular pseudobranch rests within a fretted extension of the lamellate process and this advanced feature unites the taxon.

13. Ventral pharyngeal cushion

According to Girgis (1952a,b) and Bali (1956) the "unpaired cartilagenous rod" which supports the median ridge of the ventral pharyngeal cushion in Labeinae, evolved by a fusion in the midline (and subsequent secondary reduction) of the fifth ceratobranchial. However, Nelson (1969) following Chu (1935), affirms that in cyprinids and catostomids a simple, independent fifth epibranchial is often present thus suggesting that the pharyngeal bones are derived from an extreme dorsal arching and hyperosteosis of ceratobranchial 5. This homology is a reasonable one and it falsifies the hypothesis of Girgis (1952a,b) and Bali (1956).

It seem likely that the "unpaired catilaginous rod" of Girgis and of Bali is a basibranchial bone (see Nelson, 1959:fig.19). Nevertheless, Bali (1956) uses the fact that rakers are associated with the free margin of the ventral pharyngeal cushion to support his hypothesis that the median ridge is a modified fifth gill arch. Nelson (1969,p486) states that "....there can be little doubt that gill rakers are little more than modified (dermal tooth) plates". However, it seems possible that marginal rakers represent a dermal localization which do not strictly correspond to gill rakers (i.e. branchial arch associated rakers). Such reasoning does not strengthen Bali's(1956) hypothesis. Whatever the case may be, marginal rakers are of widespread and common occurrence throughout the Cyprinidae and the number of these is invariably congruent with the numerical abundance of gill rakers on branchial arches 1-4. There is no suggestion that, in this respect, the morphology of the ventral pharyngeal cushion offers clues to labeine interrelationship.

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[5] It should be note that Taverne(1973) considers the presence of a dorsal aorta canal in the teleost *Xenomystus* to be conserved paleonisciform feature. However, Patterson(1977) consider, on the basis of other characters, that the dorsal aorta canal in *Xenomystus2 is a neomorphic character.*

14. Gill rakers

A relatively low number of fairly coarse gill rakers (20 or fewer pairs associated with each ceratobranchial bone) is a common condition throughout the cyprinids and it is unusual for the number of gill rakers to increase substantially with increasing standard length (see also Kliewer ,1970). This fact suggests that the presence in Labeini of a high number of fine, closely set gill rakers (more than 20 pairs associated with each ceratobranchial bone) is a specialization. In adult *Labeo* and certain species of *Osteochilus* (e.g. *O. waandersi*, and *O. pleurotaenia*) the gill rakers are exceedingly numerous (as many as 70-80 pairs associated with each gill arch) and they show a large numerical increase with increasing standard length. I consider this to be an advanced condition.

15. Pharyngeal bones and teeth

In erecting cyprinid phylogenies several authors have used the number, arrangement, and form of pharyngeal teeth (e.g.Chu, 1935; Tretiakov, 1946). There is, however, a great deal of controversy as to the primitive pharyngeal tooth form and primitive number of tooth rows. Chu (1935) argues that three rows of teeth are primitive but that the conical tooth form is not. Surovov (1948 -cited in Hensel,1970) considers a single row of teeth to be primitive while Matthes (1963) argues that a reduced number of tooth rows and a simple tooth form is both primitive and neotenic. On the other hand, Nelson (1969: p.513) considers that "..there is every reason to believe that multiple rows of conical teeth are primitive for any given group of teleostome fishes, for pharyngeal teeth ultimately are to be derived through assimilation of tooth plates (not well-differentiated gill rakers as Weisel, p.127, assumed -cited in Hensel, 1970) and the fusion of these with their endoskeleton supports."

As far as I can ascertain no cyprinid has more than three rows of functional teeth and there are not more then seven in row 1 (outer); four in row 2 (middle); and three in row 3 (inner), i.e. no cyprinid has more than 14 funtional teeth on each pharyngeal bone . In certain cyprinid (and catostomid) genera which have a single tooth row there are two rows of conical teeth present in early ontogeny (Vasnecov, 1939; Weisel, 1967 -both are cited in Hensel, 1970). Hoda & Tsukahara (1971:p491) note that in *Cyprinus* the adult triserial molariform dentition (dental formala 3:1:1) results from an ontogenetic loss of one tooth from the inner row and "a gradual adaptation of teeth from the (conical) carnivorous form to the omnivorous type". There is then ontogenetical evidence (albeit limited) which suggests that triserial rows of conical teeth are primitive.

Assuming this to be true, then many Barbinae and all Labeinae are plesiomorphic with respect to the number of tooth rows. Nevertheless, in Labeinae, both the spoon-shape tooth form and the crowded arrangement of teeth is derived and so too is the singular form of the plough-shape pharyngeal bone. Tooth form is essentially similar throughout the Labeinae and of little or no use when discussing interrelationships of this group, although, *Cirrhina* and *Labeobarbus* are for example unique in having a notch in the mesial sides of the crowns.

ECOLOGICAL STUDY

ECOLOGICAL STUDY

The ecology and life history of *Osteochilus* have not been studied before. A small ecological study was conducted by myself and a team from the Department of Fisheries in Thailand on Ubolratana Reservoir which has three sympatic species (*O. hasselti*, *O. lini*, and *O. melanopleura*). The study was done as part of the government's large project in the management of Ubolratana Reservoir and was not finished when I left Thailand in 1978. The project is still being conducted.

Ubolratana Reservoir is located in northeastern Thailand on the Pong River, 450 km northeast of Bangkok, Thailand. It was built mainly for electrical and irrigational purposes. The reservoir occupies a broad, flat valley among the gently undulating hills known as Phupan and Phupan Kam. It is a shallow reservoir with an average depth of 16 m and an area of 41,000 hectare at elevation of 182 m above mean sea level at its maximum storage; at its lowest level; its surface area is 16,700 hectare and the average depth 12 m. High water level usually occurs in the rainy season (July-September) and the low level in late summer. The lake bottom was, prior to impoundment, mostly paddy fields interspersed with shrubs and trees. The soil was characterized as relatively infertile, consisting of loams and sandy loam. The climate is characterized by a relatively long, hot, dry summers and moderate winters. The mean annual precipitation over the watershed is about 1200 mm. The watershed covers approximately 12,000 square-kilometers. The dam was closed in January 1965 and the reservoir filled in nine months.

Prior to impoundment, studies were conducted by Thailand's Department of Fisheries on the ichthyofauna but not on other biological conditions or on the physico-chemical condition because of limitations of staff and budget. Sidthimunka and Potaros (1968) reported that 76 species of fishes were found, mostly riverine species. The species composition was comprised mainly of carps (Cyprinidae, 31 species, contributing 59.9% by weight) and cat fishes (Siluriformes, 14 species, comprising 20.6% by weight).

Following impoundment, the temperature at the water surface closely followed atmospheric temperatures. Dissolved oxygen decreased rapidly from the depth of 5m to 10 m, whereas carbon dioxide increased. Even though no vertical temperature records were taken at that time, it was thought that a thermocline was developed somewhere near the 10 m depth. This assumption was later confimed by Shiraishi and Kimura (1971), who observed a thermocline in this reservoir between the depths of 11 m and 13 m. Further, they also observed chemical stratification similar to that of the thermal stratification.

Changes in the ichthyofauna were observed one year after the impoundment. Only 63 species were collected after 1966, compared with 76 species prior to impoundment. Of these, 54 species were present before impoundment and 9 species were new additions. Surprisingly, postimpoundment samples were dominated by carnivorous murrels (*Ophicephalus* sp.) which comprised 34.8% by weight of the catch compared to 24.1% for carps, 11.9% for catfishes, and 29.2% for others. The standing crop was estimated at 177.1 kg/ha.

Further investigations have shown fluctuations in the species composition of fishes in this impoundment. Numbers of species caught ranged from 76 species in 1965, 67 in 1969, 58 in 1975, and 52 in 1978. Several species have therefore disappeared following impoundment. There were four species of *Osteochilus* (*O. hasselt, O. melanopleura, O. lini* and *O. microcephalus*) during the preimpoundment study and three species after impoundment. *O. microcephalus* disappeared from the reservoir after 1966, and *O. hasselti* become one of the dominant species. *O. lini* has decreased in numbers and might soon disappear from the reservoir.

Habitat

Three different methods were used for sampling the fish. Electric shocking was used along rocky shores, nets were used in the deep parts, and rotenone was used in the quiet shallow areas. Collecting was not done in the open water area because of the depth, strong winds, and high waves. The results from these collection shows that there are restrictions in the habitat preference in *O. melanopleura* and *O. lini* but not in *O. hasselti*. *O. melanopleura* is a large species (usually about 20-40 cm) which was caught only by gill nets where the water was deeper than 2 m and in a large area which was occupied by dead trees half emergent in the water (the trees were not cut before impoundment). This area is mainly on the southwest side of the reservoir where the Pong mainstream flows into it. There is an abundance of fish food in this area such as crustaceans and insect larvae, which are attached to tree trunks and are fed upon by *). melanopleura*. *O. lini* is a small sized fish (usually about 7-10 cm) and is restricted to rocky shores. There are three major hills bordering the lake, two are at the dam site at the east end of the lake and the third at the south end of the lake. *O. lini* is found along the rocky shoreline of these three hills. This species generally occurs in the riverine like habitat mainly in the rocky parts of the rivers. The rocky shores of Ubolratana Reservoir probably maintains riverine conditions by surf hitting through the rocks and *O. lini* probably will be soon disappear from the reservoir. *O. hasselti* is a medium sized fish (usually 10-20 cm) which became one of the most dominant species of fish in the reservoir. It is found in all types of habitat in the reservoir, and in large numbers.

Food

Fish samples for examination of the gut contents was collected by the above methods and from commercial catches at the fish market an the southeast bank of the lake (behind the fishery station). 150 specimens of *O. hasselti*, 75 specimens of *O. lini*, and 75 specimens of *O. melanopleura* collected over a period of one year were examined for gut contents. The size of *O. hasselti* ranged from 100 mm - 230 mm total length; *O. lini* 60 mm- 120mm total length; and *O. melanopleura* 130-430 mm total length; weights ranged from 3.0 gm to 4520 gm.

After dissecting the fish, the entire alimentary canal was removed from each fish and its length in millimetres and weight in grams were recorded. Three pieces, each measuring 20 mm. in length, were cut from different regions of the alimentary canal representing the forgut, midgut, and hindgut, and their contents were emptied into a petri dish. The contents were diluted with a small quantity of distilled water and a small sample was examined under the microscope to determine the frequency of occurrence of each item of food present in the sample. For each gut, three such samples were examined and the average of each item calculated. Each item of food was then assigned a volume by eye, estimated according to the bulk of each item in the total volume of all items encountered. The data for the gut-content analysis in a particular month were tabulated and the average percentage of each item calculated.

All species of *Osteochilus* and most labeine cyprinids feed on aufwuchs and take considerable amounts of organic detritus along with other items (algae, zooplankton, diatoms etc.). Sehgal (1966) reported studying food and feeding habits of *Labeo calbasu* and noted "If mud be considered as an item of gut contents its percentage ranks the highest." Reid (1978, and per. comm.) also agrees that he had difficulty in distinguishing the food items between species of African *Labeo* as most were comprised of unidentified detritus.

In this study I found no differences in the diet of *O. hasselti* and *O. lini*, but there was a different food composition in *O. melanopleura*. The diet of *O. hasselti* consists of 81.2% detritus and 9.1% algae (mainl (mainly *Calothrix, Urothrix, Oedogonium, Spirogyra,* etc.), 4.8 % diatoms (mainly *Navicula, Cymbella, Tabellaria,* etc.), 4.1 % zooplankton (mainly rotifers and copepods), and 0.8% plant matter. The diet of *O. lini* consists of 75% detritus, 12.3% algae, 7.6% diatoms, and 5.1 % zooplankton. The diet of *O. melanopleura* consists of 62.3% detritus, 21.4% insect larvae, 8.1% crustaceans, 5.2% plant matter, and 3% algae.

Breeding Cycle

Fish in tropical waters usually spawn at least once annually and many species spawn several times a year (see also Lowe-McConnell, 1975). They have a wide range of spawning seasons which start as early as the beginning of the rainy season (June or July) when the water level is rising and there is more fresh and cool water, and ending in September to October when the monsoons cease. There is much variation in the spawning time of the species that spawn more than once a year. There are many species, especially cyprinids, in this reservoir, their spawning times are relatively close together, and several overlap in their spawning time. In the three species of *Osteochilus* the studies were done on female fishes collected monthly (1978) from various parts of the reservoir. The developmental system of the eggs was divided into four categories ranging from early development (stage 1) to fully ripe (stage 4). The month that fish have stage 4 eggs was considered to be the start of the breeding season.

The breeding season in *O. hasselti* started quite early, as with many other cyprinid fishes, and extended quite long, from June to September. The spawning season of *O. lini* completely overlapped with *O. hasselti* but extended only from June to August.

O. melanopleura started spawning later than the previous two species and had a short season extending only from July to August. This data is based on only a one-year study. The spawning season might vary between years depending on many environmental factors, especially climate, and long term studies would be desirable.

Conclusion

The results of this study show that isolating mechanisms are well developed between *O. melanopleura* and the other two species. *O. microcephalus* is strictly a riverine species which disappeared in the first year after impoundment. *O. hasselti* and *O. lini* overlap in general ecological preferences but *O. lini* is more restricted in habitat. Like *O. microcephalus, O. lini* is also a riverine species, and declined in numbers since impoundment.

DISCUSSION AND CONCLUSIONS

DISCUSSION AND CONCLUSIONS

This thesis is concerned with the comparative morphology and systematics of *Osteochilus*, a genus of tropical southeastern Asiatic cyprinid fishes which contains 51 nominal species. Two subjects of systematic importance have been tackled as follows: (i) a revition of the genus *Osteochilus*, (ii) the establishment of the phyletic relationships of the species of *Osteochilus* and the interrelationships of related genera.

A broadly based morphological approach has been used in an attempt to resolve these problems. A detailed examination of 25 selected characters on 2340 specimens of the genus *Osteochilus* and on a few species of related genera from throughout southeastern Asia has revealed more intraspecific variation than that usually encountered in fishes living under similar ecological conditions. Some species vary more than others. From another source of confusion, many also differ from their original description. Many species occur sympatrically (some with a great deal of ecological overlap and others with very little), while others are allopatric. Some have wide distributions, other are very restricted. Examination of all nominal species for which specimens are available has led to the conclusion that most of those species differing in a minimum of morphometic or meristic characters are not distinct from each other. Although hybridization is of well documented occurrence in European and North American cyprinids, there is no evidence in this study that hybridization occurs in *Osteochilus*. Neither the evolution nor the phylogeny of *Osteochilus* has been critically examined before. Furthermore, there is only one fossil known (Sanders, 1934; not seen) which is poorly diagnosed and does not assist in studying the relationships of the genus. Nevertheless, one of the purposes of the present study is to attempt to erect a phylogeny of the group.

The phyletic relationships

The 23 species of *Osteochilus* fall into two distinct groups on the basis of osteology and external morphology. One group consists of 21 species (the *O. microcephalus* lineage) and the other of three species (the *O. melanopleura* lineage). If one accepts the contention that ancestral characters can be distinguished from derived characters by the use of ex-groups then we can make decisions on the direction of evolution. In such comparisons, Ross (1974:153) states, "if one of two or more character states in one group occurs in other closely related groups (i.e., the ex-group) it is probably the ancestral one." Using this procedure, the *O. microcephalus* lineage is considered to be the most primitive because it shows more ancestral character states with the assumed more primitive genus *Labeo* than does the *O. melanopleura* lineage. The latter has more derived character states not present in *Labeo* than does the *O. microcephalus* lineage. The two lineages were probably derived from a common ancester possessing two pairs of well-developed barbels and an oblong, somewhat compressed body, low gill raker count (28-35), lips with moderately long undivided costae, large scales (l.l. 30-33, c.p. 16, c.f. 11/2/13), and club-shaped lower jaw bones. According to Lowe-McConnell (1969), older faunas are generally found in rivers and not in lakes in the tropics. This is in agreement with my observation that the primitive species of *Osteochilus* (as determined from morphological analysis) occur in large rivers and not in lakes. These rivers are older than the lakes and support older communities of fishes subject to environmental selection for a longer time. This ancestral form of *Osteochilus* was probably well adapted to the rapids of rivers and probably resembled the ancesteral species of the genus *Labeo*. This ancestral group became divided into two major groups (fig. 52), one with a deep body, large size (exceeding 300 cm in standard length), a long dorsal fin, triangular lower jaw bones, an ascending mouth, and an irregular set of small mound-shaped costae on the upper lip; the other group is postulated as remaining similar to the ancestral form and probably possessing a median longitudinal stripe and three tubercles on the snout. The difference between these two groups probably represents environmental adaptation. The first group, with an ascending mouth and deeper body, prefers the quiet back-water of rivers and probably dispersed into lakes and other slow moving water systems and gave rise to the *O. melanopleura* group with three species. The other group has a slender body with a subinferior mouth, similar to its proposed ancestor, and probably gave rise to two subgroups. One, the *O. hasselti* group with five species, possesses divided short costae on the upper lip and a long dorsal fin, and the other possesses long undivided costae on the upper lip and a short dorsal fin. The later subgroup was the ancestor of *O. triporus* and the remaining species. The second subgroup may have evolved further into two additional lines, one with species with multiple longitudinal rows of spots or stripes on the body, and the black spot on the anterior part of the dorsal fin (which became the *O. triporus* group with five species), and the other probably being ancestral to *O. microcephalus* and the remaining species. The latter may have given rise to a small subdivision with fewer lateral-line scales (27-31), fewer circumferential scales (9/2/11), and without a stripe on the body, the *O. spilurus* group (with two species). The ancestor of the remaining species probably had a median lateral stripe and three tubercles on the snout. It probably gave rise to a subdivision which has two tubercles on the snout, a diffused median lateral stripe, and a long dorsal fin; this subdivision consists only of *O. kahajanensis*. The ancestor of the remaining species may have given rise to two final subdivisions, one with a conspicuously inferior mouth, high gill raker count (40-60) (which has become the *O. waandersi* group, of four species), and the other with a subinferior mouth and low gill raker count (28-35) which became the *O. microcephalus* group with three species.

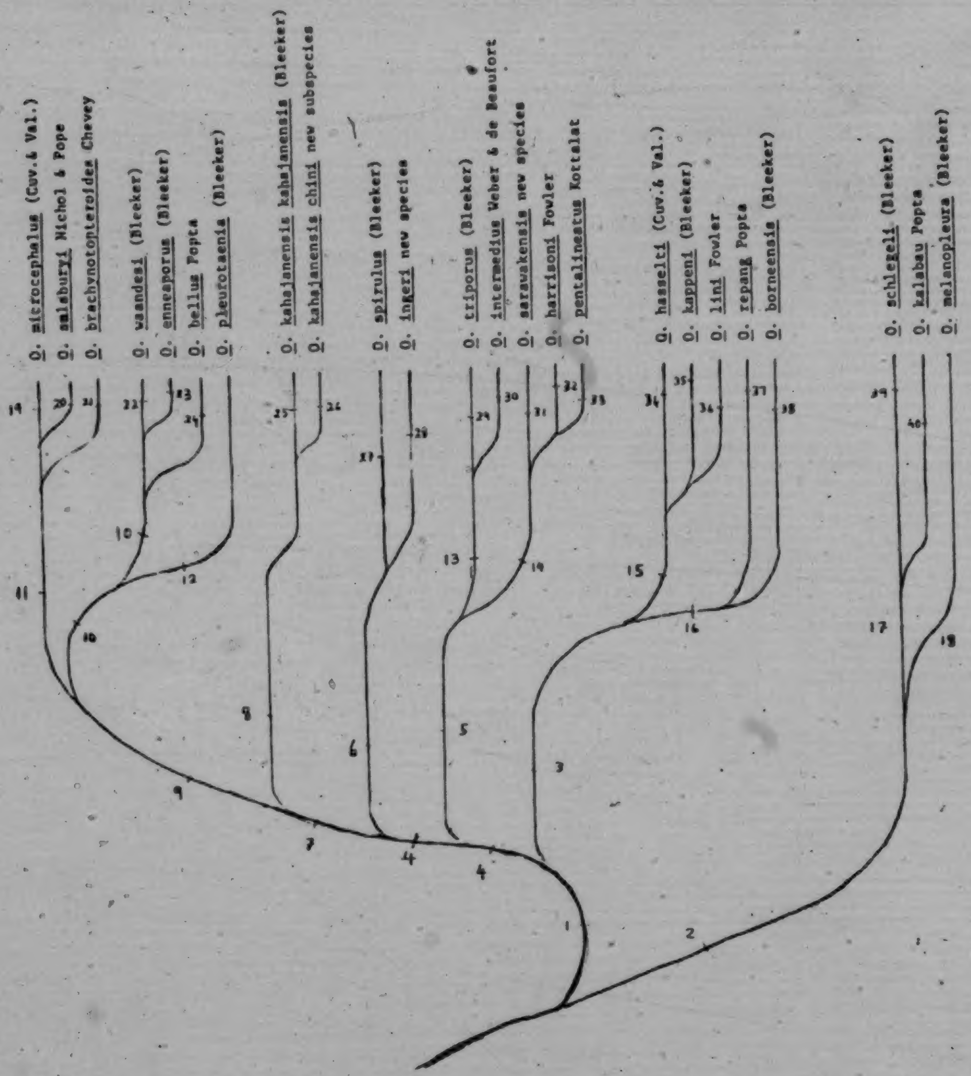
O. microcephalus (Cuv.& Val.)
O. salaburyi Nichol & Pope
O. brachynotopteroides Chevey
O. vaandesi (Bleeker)
O. enneaporus (Bleeker)
O. bellus Popta
O. pleurotaenia (Bleeker)
O. kahajanensis kahajanensis (Bleeker)
O. kahajanensis chini new subspecies
O. spirulus (Bleeker)
O. ingeri new species
O. triporus (Bleeker)
O. intermedius Weber & de Beaufort
O. sarawakensis new species
O. harrisoni Fowler
O. pentalineatus Kottelat
O. hasselti (Cuv.& Val.)
O. kappeni (Bleeker)
O. lini Fowler
O. repang Popta
O. borneensis (Bleeker)
O. schlegeli (Bleeker)
O. kalabau Popta
O. melanopleura (Bleeker)
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Fig. 52 Hypothetical phylogeny of Osteochilus
The character states used for this analysis are on the next page

Character states used in the phylogenetic analysis

1. mouth subinferior.
2. mouth ascending.
3. lip costae short and divided into 2-3 portion, long dorsal fin.
4. lip costae long and undivided.
5. rows of spots or multiple stripes on the body.
6. c.f. 9/2/11, without median lateral stripes.
7. c.f. 11/2/13, with median lateral stripes.
8. median lateral stripes diffused, two tubercles on the snout.
9. median lateral stripes distinct, three tubercles on the snout.
10. body long slender, mouth conspicuously inferior, high gill raker count.
11. body oblong, mouth subinferior, low gill raker count.
12. mouth expanded, loss of median lateral stripes (only present in young), large size.
13. black spot on anterior base of dorsal fin, rows of spots-faint.
14. no black spot on the dorsal fin, rows of spots or stripes-intense.
15. rows of spots on the posterior 2/3 of the body.
16. body plain
17. large scales.
18. very small scales.
19. three tubercles on the snout, median lateral stripe, c.f. 11/2/13.
20. loss of stripes (present in young), no tubercle on the snout, c.f. 11/2/13.
21. long, slender body, no stripe, no tubercle, c.f. 9/2/11.
22. median lateral stripe extends to the end of caudal rays, c.f. 11/2/13.
23. median lateral stripe extends to the end of caudal peduncle, c.f. 11/2/13.
24. rows of spots on the body, median lateral stripe only on posterior half of the body, c.f. 9/2/11.
25. long dorsal fin, branched dorsal rays 14-16, long body.
26. short dorsal fin, branched dorsal rays 12-14, short body.
27. small size, l.l. 27-29, g.r. 27-30.

28. medium size, l.l. 30–31, g.r. 31–42.

29. short dorsal fin (IV,11–12), low gill raker count, lip costae divided.

30. long dorsal fin (IV,13–14), high gill raker count, lip costae undivided.

31. rows of spots on the body, dorsal fin IV,11–13, c.p. 16.

32. ten stripes on the body, dorsal fin IV,15–16, c.p. 16.

33. five stripes on the body, dorsal fin IV,10, c.p. 12.

34. rows of spots on the body, c.f. 11/2/13, dorsal fin IV,15–18 (rarely 12–14).

35. rows of spots on the body, c.f. 13/2/15, dorsal fin IV,16–18.

36. loss of spots on the body, c.f. 11/2/13, dorsal fin IV,12–15.

37. large scales.

38. small scales.

39. short dorsal fin (IV,13–14).

40. long dorsal fin (IV,16–17).

The *O. microcephalus* lineage is the most primitive group. It has three closely related species. *O. microcephalus* has three tubercles on the snout and a median lateral stripe extending to the end of the caudal peduncle (primitive states). *O. salsburyi* is very similar to *O. microcephalus* but lacks of tubercles on the snout and lacks of a median lateral stripe on the body (except in some young specimens). *O. brachynotopteroides* has a longer and more slender body and has 9/2/11 (derived state) (11/2/13 in the other two species) circumferential scales.

The *O. waandersi* lineage is derived from the *O. microcephalus* lineage and is adapted to mountain stream habitats. This group consists of four species. *O. waandersi*, *O. enneaporus*, and *O. bellus* share many characters in common with the primitive *O. microcephalus*, such as a median longitudinal stripe and three tubercles on the snout. In this lineage the lip costae are more developed and the gill rakers are exceedingly numerous (40-60). The first three species mentioned above are closely related and differ only in the color pattern, except that *O. bellus* has a reduced number of circumferential scales (9/2/11). *O. pleurotaenia* is the most derived form of this lineage. It has an entire snout (there are numerous small tubercles in some large specimens), reaches a large size (up to 300 mm), has a median lateral stripe in some young specimens, and has expanded lips which are more developed than other species of *Osteochilus*.

The *O. kahajanensis* lineage consists of one species with two subspecies. *O. kahajanensis kahajanensis* is distributed in Borneo (except northeastern Borneo), Sumatra, Java, and Malay Peninsula. It has a long dorsal fin (IV,15-16, rarely 14), with a rather moderately deep body (depth 347). *O. kahajanensis chini* is restricted to northeastern Borneo. It has a short dorsal fin (IV,12-14), with a rather deep body (depth 362). The derived character that is unique in this lineage is the occurrence of two tubercles on snout.

The *O. spilurus* lineage has only two species. *O. spilurus* is a small species (size rarely exceeding 70 mm in standard length), and with few lateral line scales (27-29) and gill rakers 28-30. *O. ingeri* is a medium size species (up to 120 mm standard length) with more number of lateral line scales (30-31) and gill rakers 40-45. Derived characters that are unique in this group are the reduction of the number of the lateral line and circumferential scales and loss of tubercles on the snout.

The *O. triporus* lineage consists of five species. The character that unites this group is the rows of spots on the body. *O. triporus* is the only species in this group that primitively has three tubercles on the snout; the others lack tubercles. *O. triporus* and *O. intermedius* have many characters in common such as a black spot on the anterior base of the dorsal fin which is presumably primitive (shared with the out group *O. shlegeli*). *O. intermedius* has more gill rakers (37-50 vs 28-31), a longer dorsal fin (IV,13-14 vs IV,11-12), and fewer circumferential scales (9/2/13 vs 11/2/11-13) than the others. The other species lock a black spot on the dorsal fin but have a row of distinct spots on the body which usually form longitudinal stripes in adult specimens (derived state). *O. sarawakensis* has a short dorsal fin (IV,11-13) and about seven to eight rows of spots or stripes on the body; *O. harrisoni* has a long dorsal fin (IV,15-16) and about ten stripes on the body; *O. pentalineatus* has a short dorsal fin (IV,10) and five stripes on the body.

The *O. hasselti* lineage consists of five species. A derived character that unites this group is the short divided costae on the lateral part of the upper lip. *O. hasselti* and *O. kappeni* share many characters in common such as rows of spots on the body, a long dosal fin (IV,15-18, rarely 13-14), and the absence of tubercles on the snout. These two closely related species can be best distinguished by the number of circumferential scales; *O. hasselti* has 11/2/13 (the primitive state) but *O. kappeni* has 13/2/15 (the derived state). *O. lini* has a plain body coloration, except for two or three black spots above the pectoral fin, a relatively short dorsal fin (IV,12-14, rarely 15), and no tubercles on the snout. The two other species, *O. repang* and *O. borneensis*, have three tubercles on the snout and a long dorsal fin (IV,16-17). *O. repang* has large scales (l.l.32) but *O. borneensis* has small scales (l.l. 47-49).

The *O. melanopleura* linage consists of three species. A derived character that unites this group is an ascending mouth which results from a modified triangular lower jaw bone. *O. schlegeli* and *O. kalabau* have large scales (l.l. 32–35), a primitive character; *O. schlegeli has 20 circumpeduncular scales and a short dorsal fin (IV,13-14) while O.kalabua* has 22 circumpeduncular scales and a long dorsal fin (IV,16). *O.melanopleura* has small scales (derived state) (l.l. 45–53, c.p. 22–24), and a long dorsal fin (IV,17–18).

O. hasselti is quite variable, especially in the number of the dorsal fin rays; depending on the geographical area it can be 12–13, 14–16, or 15–17. The color pattern of this species is also quite variable. Many young specimens have a black blotch above the pectoral fin. This is the nominal form of *O. neilli* (Day) and *O. duostigma* Fowler. In addition, all specimens have rows of spots along the body which sometimes disappear after preservation in alcohol; *O. kuhli* (Bleeker) represents a form described after preservation and without the spots.

The relationships of *Osteochilus* to other genera of cyprinid fishes had not been discussed until Reid (1978, unpublished Ph.D. thesis) proposed the subfamily Labeinae which included *Labeo, Osteochilus*, and a few other genera. Reid's hypothesis is based on the anatomy of soft parts of the oromandbular region. I have reexamined these organs and studied the osteology in many genera of labeine cyprinids in order to evaluate the status of Reid's subfamily Labeinae. The results of my studies generally seem to agree with the cladogram constructed by Reid (fig. 34), I disagree with Reid in the subdivision of the subfamily into tribes of **Tylognathini** and **Labeini**. In my opinion, *Cirrhinus* and *Labiobarbus* are more closely related to *Tylognathus* than to *Labeo* and they should be included in Tylognathini.

Specializations which unite Labeinae are as follows: (i) the occurrence of a vomoro–palatine organ, (ii) the occurrence of a terete process of the basioccipital bone, (iii) having the neural complex of Weberian apparatus in direct contract with the supraoccipital region of the skull, and (iv) the occurrence of the precoronoid arm of the lower jaw bone. Specializations which unite *Osteochilus* are as follows: (i) the unculiferous costate surface of the upper and lower lips, (ii) the reduction of the mesial process of the autopalatine, and (iii) the shape of the maxillary and dentary bone

The genus *Osteochilus*, as presently conceived, is a monophyletic genus. The genus has been previously recognized with species referable to the genera *Labeo, Cirrhinus*, and *Tylognathus*. The sister group of the redefined *Osteochilus* is *Labeo* (as revised by Reid, 1978) and these genera are included together with *Lobocheilus* in the tribe **Labeini** The Labeini is the primitive sister group of the **Garrini** and both form the derived sister group of the **Tylognathini**. The Garrini contains several taxa presently considered to be genera as follws: *Garra, Semilabeo* (not seen), *Crossocheilus, Epalzeorhynchos*, and *Mekongina*. The primitive tribe, Tylognathini includes those species belonging to the *Labeo diplostomus* group which are referable to *Tylognathus*; it also includes *Barbichthys, Cirrhinus*, and *Labiobarbus*. There are a few more genera that are considered to be included in this subfamily such as *Paracrossocheilus, Schismatorhynchus, Henicorhynchus*, etc. I lack specimens of these genera and so do not place them in the classification. This would be an interesting subject for future study.

Ecology

The ecology of *Osteochilus* is very poorly known and has never been critically studied before. I have conducted a small ecological study for three sympatric species in Ubolratana Reservoir, northeastern Thailand. The results of this study show that there are no differences in the food intake and breeding cycle between *O. hasselti* and *O. lini*, but that there are some differences in the food of *O. melanopleura*. Both *O. hasselti* and *O. lini* have a subinferior mouth while *O. melanopleura* has an ascending mouth and feeds on more crustaceans and insect larvae than the former species. *O. lini* and *O. melanopleura* are more restricted in habitat selection than *O. hasselti*.

Zoogeography

This study recognizes 23 species of *Osteochilus* as follows: 1 in Burma; 2 in northern Thailand; 5 in central Thailand; 4 in the Mekong Basin (northeastern Thailand, Loas, Cambodia, and South Vietnam); 1 in middle Vietnam; 1 in southern China and North

Vietnam; 7 in the Malay peninsula; 12 in southern Sumatra; 13 in western Borneo (mainly Kapuas Basin); 7 in southern Borneo and Java; 5 in Sarawak (northwestern Borneo); 6 in eastern Borneo (mainly Mahakam Basin); and 2 in northeastern Borneo (State of North Borneo, Malaysia) (see map fig. 1).

Many of the species are shared among these regions. At least nine species occur in three or more of the above metioned regions. The widest ranging species are *O. hasselti* and *O. microcephalus* which are found in a large part of mainland Southeast Asia and also on the islands of the Indoaustralian archipelago west of Wallace's line. Some species have very restricted distributions and on the basis of known collections are found in only a few localities of one river system (*O. repang, O. kappeni*, etc.). No specimens have ever been taken in the adjacent oceans or even in brackish water in the estuaries. Western Borneo and southern Sumatra have the greatest number of species. Thus, the area of greatest taxonomic differentiation is isolated from the remaining areas by ocean and mountain barriers. If maximum differentiation is indicative of the center of origin, then this isolated area would be the center for *Osteochilus*. However, there is considerable controversy over the criteria for postulating centers of origin, and neither maximum diversity nor other criteria provide a satisfactory conclusion (see also Croizat, et al., 1974; Briggs, 1974, 1979). I do not think that any subregion of southeastern Asia can be claimed to be the center of origin of *Osteochilus*, but the southern part of southeastern Asia is thought to have been the center of dispersal of this and many other cyprinine fishes (Banarescu, 1971, 1975; Darlington, 1957).

The question arises as to why certain subregions now separated by salt water have several species of *Osteochilus* in common since all species of the genus are confined to freshwater. The answer is based on the geological history of these land masses. There are connections between the East Indian Islands and also between these islands and the Malay Peninsula in the early Mesozoic period, and after that they started separating from each other and also from the continent because of rising water levels until they became completely separated in the upper Cretaceous (Audley-Charles, 1966). Of more significance in interpreting the biogeography of recent organisms, however, is the fact that these land masses were connected to each other and also to the mainland several times during the Ice age (in the Pleistocene) and perhaps as recently as within early historic time (this area during emergence is called Sundaland). They again separated as they are at the present time (de Beaufort, 1951; Darlington, 1957; and Keast, 1968). The Pleistocene glacial maximum was marked by a fall in the sea level of the Pacific Ocean up to 100 meters (Keast, 1968: P. 374-375), and this brought the Southeast Asian mainland and the East Indian Islands into broad contact with each other (the deepest part of the sea between Thailand and Borneo is about 73.8 meters, most of the area is about 30-70 meters, National Geographic map, 1967). At this period of time the river systems from these subregions must have flowed into the South China Sea in the area east of the Malay Peninsula at about a mid-point between South Vietnam and Borneo (see fig. 54). The area between Borneo and Sumatra, the center part of Sundaland, was drained mainly by the North Sunda River and its tributaries (Molengraaf, 1921, 1929; Brittan, 1954; Banarescu, 1975). The great North Sunda River is thought to have served as an evolutionary center during the Pleistocene and it probably had a large and varied fauna of *Osteochilus* and species of other genera of freshwater fishes which may be the same as those existing in the region today. *Osteochilus* may have been distributed extensively throughout the region. When the recent subsidence occurred, the main stream was submerged but the upper course of the tributary streams, reaching into Borneo, Malay Peninsula, and Sumatra, remained populated with the species common to the entire river system, as well as later coming to contain those forms subsequently evolved.

	O. *microcephalus*	O. *salsburyi*	O. *brachynotopteroides*	O. *waandersi*	O. *enneaporus*	O. *bellus*	O. *pleurotaenia*	O. *kahajanensis kahajanensis*	O. *kahajanensis chini*	O. *spirulus*	O. *ingeri*	O. *triporus*	O. *intermedius*	O. *sarawakensis*	O. *harrisoni*	O. *pentalineatus*	O. *hasselti*	O. *kappeni*	O. *lini*	O. *repang*	O. *borneensis*	O. *schlegeli*	O. *kalabau*	O. *melanopleura*
Burma																	X							
S.China & N.Vietnam		X																						
Middle Vietnam	X		X																					
Mekong Basin (N.E.Thailand, Laos, Cambodia, S.Vietnam)	X																X		X					X
Central Thailand	X			X													X					X		X
Malay Peninsula	X			X	X			X		X							X					?		X
South Sumatra	X			X	X		X	X		X		X	X				X				X	X		X
West Borneo	X			X	X		X	X		X		X	X				X	X			X	X		X
South Borneo & Java	X			X			X	X		X						X	X							X
Sarawak (Northwest Borneo)	X				X			X						X	X		X							
East Borneo	?			?	X	X	X	?									?			X		X	X	
Northest Borneo									X		X													

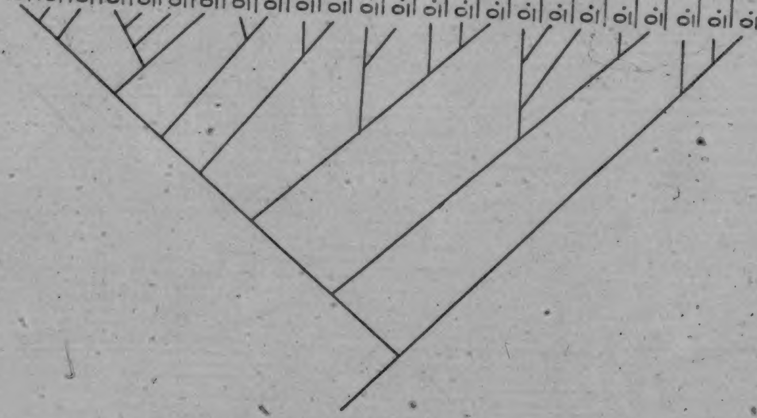

Fig. 53 Hypothetical phylogeny of *Osteochilus* with their distribution.

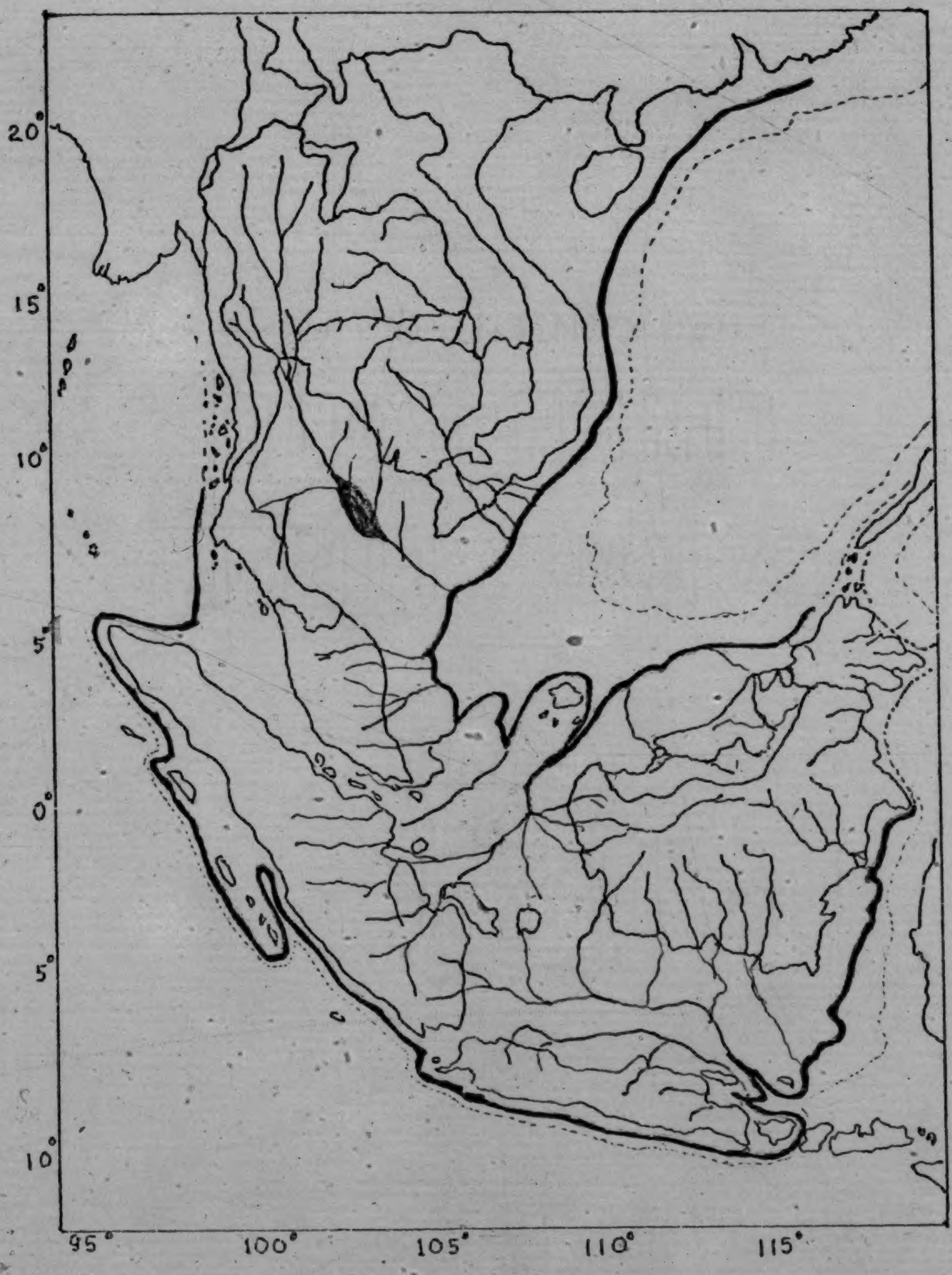
20°
15°
10°
5°
0°
5°
10°
95°
100°
105°
110°
115°

Fig. 54 The pleistocene Sundaland, thick line indicates limits of Sundaland, thin line indicates the present lands and river systems.

Brittan (1954) catagorized various species of *Rasbora* as representing an "old" fauna and a "new" fauna. The older fauna comprises those species that occupied the river systems of those portions of the Greater Sunda Islands that remained emergent during the Tertiary; they migrated there from mainland southeastern Asia, probably during the Paleocene. This fauna exists today in rivers of the Greater Sunda Islands and many of the species survive in those systems which remained isolated (eastern and North Borneo, e.g. the Mahakam). The newer fauna comprises those species more recently evolved and dispersing after the Pleistocene emergence; they partially replaced the older fauna in the area west of Borneo, Sumatra, and Maley Peninsula which shared the same drainage during the Pleistocene.

It is clear that neither the Mahakam (in eastern Borneo) nor the basins of North Borneo had excess to this Sundaland fauna except through the limited possibilities of stream piracy at the heads of the watersheds. Thus the differences in the duration of isolation from the fauna of Sumatra and the Malay Peninsula would lead to a higher percentage of endemism (24% of the endemics in Borneo are in North Borneo, Inger and chin, 1962) in the faunas of the Mahakam (6 species, 3 endemic) and North Borneo (2 species, 2 endemic) than in those of the Kapuas and Baram (western and northwestern Borneo). The Mahakam, because its sources interdigitate with those of the Kapuas and the Rajang (western Borneo), has probably had more opportunities for fauna mixing with the common Sundaland fauna through the agency of stream piracy than have the basins of eastern North Boeneo.

Southern Borneo and Java share several species since they shared the same drainage during the Pleistocene (but they were isolated from the North Sunda River). The number of species here is eight and it declines toward the eastern end of Java and the island of Bali (which is at the southeastern end of the range of *Osteochilus* and close to Wallace's line) and only one species, has been found (*O. hasselti*). Only one endemic species has been found in southern Borneo and none in Java. Southern Borneo is not completely isolated from western Borneo; there are no large mountains between them. This probably explains the lower percentage of endemism in this area, but more collections are needed in order to be sure. Java is a long narrow island which is also poorly collected. It has six or seven species most of which are in the western end and probably only one or two species are at the eastern end. This narrow island is without large river systems and is the area of active volcalnic activities; this has probably limited the number of species.

Violent volcanic eruptions are considered to have caused the disappearance of faunas from large areas (Banarescu, 1975). It is easy to imagine the catastrophic effects of such eruptions on the faunas. They are probably the cause of the great scarcity of some organisms in parts of Southeast Asia where volcanic activities are known to have been common.

Northwestern Borneo (Sarawak and Brunai) is isolated from the rest of Borneo by high mountain ranges. This area has six species; two are endemic and the other species are shared with western Borneo, Sumatra, and the mainland. There are two important tributaries in this subregion, the Baram and the Rajang-Baleh tributaries. The headwaters of the latter interdigitate with the Kapuas and Mahakam; the Baram has it headwaters close to the Kajan of eastern Borneo. Some mountain species might have dispersed by stream piracy such as *O. enneaporus* and the ancestor of the *O. triporus* group that gave rise to two endemic species, *O. harrisoni* and *O. sarawakensis*. The lowland species such as *O. hasselti* and *O. microcephalus* probably immigrated through the Sundaland emergance.

Western Borneo and southern Sumatra seem to have been an evolutionary center during the Pleistocene and they share almost the same species; western Borneo has 13 species and Sumatra has 12 species, the greatest number of species in the whole range. There are four endemic species in this area and one species, *O. kappeni*, is endemic to the Kapuas. The similarity and the richness of the fauna in these two subregions strongly suggests that they were still connected to each other while the mainland had already been separated by the sea level. The two subregions also probably were separated and connected many times in the Pleistocene and during this time there presumably was much allopatric speciation which accounts for it having the richest fauna in the area.

The Malay Peninsula has seven species, all of which are shared with Sumatra and Borneo. This peninsula probably became separated from Sundaland before Sumatra and Borneo were separated and like Java there are no large river systems in the peninsula; therefore, there are fewer species here than in Sumatra and Borneo. The Malay Peninsula is a long narrow area similar to Java and has only short river systems and has a less heterogenious in habitat which may be why there are no endemic species in this subregion.

Central Thailand has five species, all of which occur in the Malay Peninsula, Sumatra, and Borneo. Central Thailand is the farthest from the center of abandance compared to the previous subregions and probably separated first from the Sundaland. Only five species were able to immigrated to this region.

The Mekong Basin (northeastern Thailand, Laos, Cambodia, and South Vietnam) was isolated from the Sundaland and has only four species; one is endemic and the other three species are shared with other regions. *Osteochilus* probably dispersed from central Thailand to northestern Thailand and also from southeastern Thailand through Cambodia. Certain species finally gave rise to the endemic species, *O. lini*.

The question arises as to why Burma and China each have only one species of *Osteochilus*. There are probably several explanations. First of all, the mountain ranges which extend from the north to the south of Thailand, between Burma and Thailand (except the present passes at the lower part of Tak Province and the upper part of Karnjanaburi Province), may have been a geographical barrier to the immigration of other species. Secondly, there is no river system linking Thailand and Burma except for the Salween which drains only the northwestern corner of Thailand, a region of Thailand with only two species (*O. hasselti* and *O. microcephalus*). Thirdly, it is possible that at some times there was a river system which connected the two present political areas, and that river capture occurred but that only *O. hasselti* penetrated to the west. Finally, water temperature and current may be an isolating barrier for other species of *Osteochilus*, with only *O. hasselti* able to disperse into Burma. This species, however, does not occur in the northern part of Burma, but is found in the southern part of Irrawaddi and

Sittang Rivers. There are four species in the Mekong River (*O. microcephalus*, *O. melanopleura*, *O. hasselti*, and *O. lini*), but there is only one species that lives in the southern part of China (*O. salsburyi*, which is closely related to *O. microcephalus*). It is most likely that water temperature and swift-flowing stretches of rivers have been a major barrier to the penetration of other species.

There is no well marked association between the extent of a species range and its phylogenetic position. For example, of the three most widely distributed species, one (*O. microcephalus*) is relatively primitive, one (*O. hasselti*) is intermediate, and the other (*O. melanopleura*) is advanced.

O. triporus lineage is restricted to Borneo, only two species of this group occur in Sumatra (*O. triporus* and *O. intermedius*). The *O. waandersi* lineage is limited to Malay Peninsula, Sumatra, and Borneo and only one species (*O. waandersi*) occurs up to the southern part of central Thailand. Temperature and climate are probably part of the limiting for these species as the temperature on the mainland fluctuates a great deal more than on the tropical islands.

Many genera of cyprinids, e.g. *Labeo*, *Barillius*, and *Garra*, have disjunct distributions in Africa and Southeast Asia (Oriental region). Howes (1980), explains the biogeography of barilliine cyprinids by vicariant events occurring after the break-up of Gondwanaland (Indian plate and Southeast Asian block from Africa). The recent views concerning the Gondwanian position of the Southeast Asian block and its likely connection with India were published by Burton (1970) and Ridd (1971). However, Stauffer (1974) did not agree with this proposed juxtaposition of the Malay peninsula with India, but believed the Southeast Asian block once had an African connection. However, there is a controversy over the concept of a Gondwanian origin of cyprinid fishes, and more study of geology and paleoichthyology is needed to prove this concept. Species of *Osteochilus* are restricted to Southeast Asia. Therefore, if this concept is true, then *Osteochilus* must have arisen sometime after the break-up of the Southeast Asian block from Africa and spread to the mainland of Southeast Asia when it became connected.

REFERENCES

REFERENCES

Ahl, E. 1922. Einige neue Susswasserfische des Indo-Malayischen Achipels. Sitzungsberichte der Gesellschaft Naturforchender Freunde zu Berlin. 1922(1-2): 30-36.

Ahmad, N. 1944. The spawning habits and early stages in the development of the carp *Labeo gonius* (Hamilton), with hints for distinguishing eggs, embryo and larvae of *Labeo gonius, Cerrhina mrigala,* and *Wallagonia attu.* Proc. Natn. Inst. Sci. India. 10(B): 343-354.

Ahmad, N. R. 1967. Observations on the effects of feeding *Labeo rohita* (Ham.) with *Microcystis aeruginosa* Kutz. Hydrobiologia. 29:388-392

Ahmad, N. D. and R. A. Akhtar. 1967. Food of major carps. Pakist. J. Sci. 19: 116.

Alexander, R. McN. 1966. The functions and mechanisms of the protrusible upper jaws of two species of cyprinid fish. Proc. Zool. Soc. Lond. 149: 451-473.

-----. 1967. Functional design in fishes. London: Hutchinson Univ. Lib. 160pp.

Alfred, E. R. 1971. The Malayan cyprinid fishes of the sub-family Garrinae. Fedn. Mus. J. (N.S.). 16: 97-103.

Al Hussaini, A. H. 1949. On the functional morphology of the alimentary tract of some fish in relation to differences in their feeding habits: Anatomy and Histology. Q. Jl. Microsc. Sci. (3). 90(10):109-139, 323-354.

Allen, K. R. 1969. Distinctive aspect in the ecology of stream fish. J. Fish. Res. Brd. Can. 26(6): 1429-1439.

Allis, E. P. 1917. The lips and the nasal apertures in the gnathostome fishes and their homologues in the higher vertebrates. Proc. Natn. Acd. Sci. U.S.A. 3(2):73-78.

-----. 1932. Concerning the nasal aperture, the lachrymal canal and the buccopharyngeal upper lip. J. Anat. 66: 650-656.

Anson, B. J. 1929. The comparative anatomy of the lips and labial villi of vertebrates. J. Morph. Philad. 47(2): 335-394.

Audley-Charles, M. G. 1966. Mesozoic palaeogeography of Australia. Palaeogeogr. Palaeoclimat. Palaeoecol. 2(1): 1-25.

Bali, V. K. 1956. On the vestigial fifth gill-arch in *Labeo calbasu* (Ham.). J. Zool. Soc. India. 8(1): 95-98.

Ballintijn, C. N., A. Van Den Berg, & B. P. Eberink. 1972. An electromiographic study of the adductor mandibulae complex of a free swimming carp (*Cyprinus carpio*). J. Exp. Biol.. 57(1): 261-283.

Banarescu, P. 1971. Competition and its bearing in the freshwater fauna. Rev. Roum. Biol. (Zool.). 16(3): 153-164.

-----. 1972. The east Asian species of *Cirrhinus* (Pisces, Cyprinidae). Revue. Roum. Biol. (Zool.). 17(4): 251-265.

-----. 1973. Notes on the east Asian genus *Semilabeo* Rendahl, 1932 (Pisces, Cyprinidae). Revue. Roum. Biol. (Zool.). 18(2): 103-110.

-----. 1975. Printsiples and problems of zoogeography (translated from Roumanian), U.S. Department of Commerce. Washington, D.C. 214 pp.

Banister, K. E. 1973. A revision of the large *Barbus* (Pisces, Cyprinidae) of east and central Africa. Bull. Br. Mus. Nat. Hist. (Zool.). 26(1): 1-148.

Bayly, I A. E., & W. D. Williams. 1973. Inland water and ecology. Longman. 316pp.

Bleeker, P. 1851a. Neiwe bijdrage tot de kennis der ichthyologische fauna van Borneo, met beschrijving van eenige nieuwe soorten van zoetwatervisschen. Nat. Tijdschr. Ned. Indie.. 1: 259-275.

-----. 1851b. Vijsde bijbrage tot de kennis der ichthyologische fauna van Borneo,met beschrijvingvaneenige nieuwe soorten van zoetwatervisschen. Nat. Tijdschr. Ned. Indie.. 2: 415-442.

-----. 1852a. Zesde bijdrage tot de kennis der ichthyologische fauna van Borneo. visschen van pamangkat, Bandjermassing, Braboekarta en Sampit. Nat. Tijdschr. Ned. Indie.. 3: 407-442.

-----. 1852b. Diagnostische beschrijvingen van nieuwe op weinig bekende vischsoorten van Sumatra. Tiental -V. Nat. Tijdschr. Ned. Indie.. 3:569-608.

-----. 1852c. Nieuwe bijdrage tot de kennis der ichthyologische fauna van het eilamd Banka. Nat. Tijdschr. Ned. Indie.. 4: 715-738.

-----. 1953. Nalezingen op de ichthyologische fauna van ket eiland Banka. Nat. Tijdschr. Ned. Indie.. 5: 175-194.

----. 1855. Nalenzingen op de vischfauna van Sumatra. Visschen van Lahat en Sibogha. Nat. Tijdschr. Ned. Indie.. 9: 157-280.

-----. 1857a. Tiende bijdrage tot de kennis der ichthyologische fauna van Borneo. Visschen van de rivieren Barito, kahajan en Kapoeas. Act. Soc. Sci. Indo-Neerl.. 2: 1-21.

-----. 1857b. Descriptiones specierum piscium javanensium novarum vel minus cognitarum diagnosticae. Nat. Tijdschr. Ned. Indie.. 13: 323-368.

-----. 1860. Ichthyologiae Archipelagi Imdici Prodromus. Ciprini. Batavia: Lange and Co. 2: 492pp.

-----. 1863. Atlas ichthyologique des Indes Orientales Neerlandaises. 3 Cyprins. Amsterdam: De Breuk and Smits. 150pp.

-----. 1865. Sixieme notice sur la faune Ichthyologique de Siam. Ned. Tijdschr. Dierk. 2: 171-176.

Boulenger, G. A. 1907. Zoology of Egypt: Fishes of the Nile. London: Hugh Rees. 170-173.

-----. 1909. Catalogue of the freshwater fishes of Africa in the British Museum (Natural History). 1:300-343.

Briggs, J. C. 1974. Operation of zoogeographic barriers. Syst. Zool.. 23:248-256.

----. 1979. Ostariophysan zoogeography: an alternative hypothesis. Copeia 1979(1): 111-118.

Brittan, M. R. 1954. A revision of the Indo-Malayan fresh-water fish genus *Rasbora*. Manila Bureau of Printing. 224 pp.

Burton, C. K. 1970. The palaeotectonic status of the Malay Peninsula. Palacageogr. Palaeoclimate. Palaeoecon. 7: 51-60.

Cadwalladr, D. A. 1965. Notes on the breeding biology of *Labeo victorianus* Boulenger (Pisces: Cyprinidae) of Lake Victoria. Revue. Zool. Bot. Afr.. 72(1-2):109-134.

Casati, E. 1923. Interne al centri e alle vic qustatore del cervello di *Carassius auratus*: Contrbute alle studio comparative del systema nervose centrale dei Teleostei. Atti. Accad. pontif. Nuovi Lincei (5). 32(1):531-535.

Chacko, P. I. & S. Subramanian. 1946. Food and feeding habits of Labeo boggo (Sykes). Proc. Indian Sci. Congr.. 36(3):168.

Chakrabarty, R. D. & D. S. Murty. 1972. Life history of Indian major carps *Cirrhinus mrigala* (Ham.), *Catta catta* (Ham.), and *Labeo rohita* (Ham.) J. Inld. Fish. Soc. India. 4:132-161.

Chauduri, B. L. 1912. Description of some new species of freshwater fishes from north India. Rec. Indian Mus. 7:137-144.

Chevey, M. P. 1934. Description de deux Cyprinidae nouv ux du lac de Kontum (Annam). Bull. Mus. Nat. Hist. Natu. (2e serie). 6:32-35.

Chu, Y. T. 1935. Comparative study on the scales and on the pharyngeals and their teeth in Chinese cyprinids, with particular reference to taxonomy and evolution. Biol. Bull. St. John's Univ. Shanghai. 2:1-225.

Corbett, P. S. 1961. Food of non-cichlid fishes in Lake Victoria basin. Proc. Zool. Soc. Lond. 139(1): 1-101.

Croizat, L., G. Nelson, and D. E. Rosen. 1974. Center of origin and related concepts. Syst. Zool. 23: 265-287.

Cuvier, G. L. C. F. D. 1817. Le regne animal distribue d'apres son organization, pour servir de base a l'historie naturelle des animax et d'introduction a l'anatomic comparee. 2:194.

Cuvier, G. L. C. F. D. and A. Valenciennes. 1842. Histoire naturalle des poissons. 16:472pp.

Darlington, P. J., Jr. 1957. Zoogeography: The geographical distribution of animal. John Wiley, New York.

Darwin, C. 1859. The origin of species, by means of natural selection. London: John Murray. 490 pp.

Das, S. M., & S. K. Moitra. 1963. Study on the food and feeding habits of some freshwater fishes in India, Part. IV: A review on the food and feeding habits with general conclusions. Ichthyologica. 2:107-115.

Das, S. M., and S. Nath. 1965. The comparative anatomy of the alimentary tract and its modification in relation to the food and feeding habits in some fishes in Jammu

Province (India). Ichthyologica, Kanpur. 4:63-78.

Das ,S. M., and B. A. Subla. 1964. The oral valves of Kashmir fishes. Kasmir Sci. 1(1-2):27-34.

Datta, Munshi, J. S.; and B. P. Singh. 1966. The cranial muscle and the natural mechanism of openning and closing of mouth in the Indian major carps. Zool. Anz. 178(1-2):49-60.

Day, F. 1873. On some new or imperfectly known fishes of India and Burmah. Proc. Zool. Soc. London. 1873:107-110.

-----. 1876. The fishes of India; being a history of the fishes known to inhabit the sea and freshwaters of India, Burma, and Ceylon. 1:816 pp.

-----. 1889. The fauna of British India, including Ceylon, Burma. Fishes. London: Taylor and Francis. 1:1-548.

de Beaufort, L. F. 1951. Zoogeography of the land and inland waters. Sidgwick and Jackson Ltd., London. 208 pp.

Dorier, A. and G. Bellon. 1951/52. Sur l'organ palatin des cyprinids. Trau. Lab. Hydrobiol. Piscic. Univ. Glenoble. 43-44: 47-60.

Eastman, J. T. 1971. The pharyngeal bone musculature of the carp (*Cyprinus carpio*). J. Morph. 134:131-140.

Edwards, L. F. 1930. Origin of taste buds in the oro-pharyngeal cavity of the carp (*Cyprinus carpio* Linnaeus). Ohio J. Sci. 30(6):385-395.

Evans, H. E. and E. E. Duebler. 1955. Pharyngeal tooth replacement in *Semotitus atromaculatus* and *Clinostomus elongatus*, two species of cyprinid fishes. Copeia 1955(1): 31-41.

Fiebiger, J. 1931. Uber den Bua und die Mechanik des Karpfenrussels. Z. Mikrosk. -Anat. Forsch. Leipzig. 27:582-612.

Fowler, H. W. 1905. Some fishes from Borneo. Proc. Acad. Nat. Sci. Philadelphia. 57:455-523.

-----. 1934. Zoological results of the third de Schauensee Siamese Expedition Part 1. Fishes. Proc. Acad. Nat. Sci. Philadelphia. 86:67-163.

-----. 1935. Zoological results of the third de Schauensee Siamese Enpedition Part 6. Fishes obtained in 1934. Proc. Acad. Nat. Sci. Philadelphia. 87:89-163.

-----. 1937. Zoological results of the third de Schuensee Siamese Expedition. Part 8. Fishes obtained in 1936. Proc. Acad. Nat. Sci. Philadelphia. 89: 125-264

-----. 1976. A catalogue ot world fishes (XXIV). Quarterly Journal of the Taiwan Museum. 29(1-2):1-110.

Frank, S. 1965. A contribution to the knowledge of the pharyngeal filter of some species of fishes of the suborder Characinoidei and Cyprinoidei. Vestn. Cesk. Spol. Zool. 29:146-155.

Fryer, G. 1959. The trophic ineterrelationships and ecology of some littoral communities of Lake Nyasa with especial reference to the fishes, and the discussion of the evolution of a group of rock frequenting Cichlidae. Proc. Zool. Soc. London. 132 (2):153-281.

Fryer, G. and P. J. B. Whitehead. 1959. The breeding habit, embryology, and larval development of *Labeo victorianus* (Pisces:Cyprinidae). Rev. Zool. Bot. Afr. 59 (1-2): 31-49

Gauthier-Lievre, L. 1949. Lists des algues provenant de contenue intestinaux de poissons du Niger moyen. Cybium. 4:55-61

Gillbert, C. R. and R. M. Bailey. 1972. Systematics and zoogeography of American cyprinid fish, *Notropis (Opsopoedus) emiliae*. Occ. Pap. Mus. Zool. Univ. Mich. 664:1-35.

Girgis, S. 1952a. The bucco-pharyngeal feeding mechanism in an herbivorous bottom-feeding cyprinid, *Labeo horie* (Cuvier). J. Morph 90(2):281-316.

-----. 1952b. On the anatomy and histology of the alimentary tract of a herbivorous bottom-feeding cyprinoid fish, *Labeo horie* (Cuvier). J. Morph. 90(2):317-362.

-----. 1953. Glands of the alimentary canal of a cyprinid fish, *Labeo horie* (Cuvier). Bull. Zool. Soc. Egypt. 11:52-58.

Goorts, P., N. Magis and J. Wilmet. 1961. Les aspects biologigues, humains et economiques de la peche dans le lac barrage de la Lufira. F.U.L.R.E.A.C. :127 pp.

Goren, N., L. Fishelson and E. Trewavas. 1973. The cyprinid fishes of *Acanthobrama* Heckel and related genera. Bull. Br. Mus. Nat. Hist.(Zool.) 24(6):291-315.

Gosline, W. A. 1973. Considerations regarding the phylogeny of cypriniform fishes with special reference to strucutre associated with feeding. Copeia 4:761-776.

Granel, F. 1926. Strucutre histologique de la pseudobranchie des poissons. C.R. Soc. Biol. Paris. 182:284-286.

------. 1927. La pseudobranchie des poissons. Archs. Anat. Microsc. 23(2):175-317.

Gratzionow, V. 1900. Uber die Sog "Kauplatte" der Cyprinoiden. Zool. Anz. 23:66-73.

Greenwood, P. H. 1972. New fish fossils from Pliocene of Wadi Natrun, Egypt. J. Zool. London. 168:503-519.

Greenwood, P. H. and R. A. Jubb. 1967. The generic identity of *Labeo quathlambae* Barnard (Pisces, Cyprinidae). Ann. Cape. Prov. Mus. (Nat. Hist.) 6(2):17-37.

Gunther, A. 1868. Catalogue of the fishes in the British Museum. British Museum, London. Vol. 7: 512 pp.

Hamilton-Buchanan, F. 1823. An account of the fishes found in the river Ganges and its branches. Archibal Constable & Co., Edinburgh. 405pp.

Hara, T. J. 1971. Chemoreception. In:Hoar, W.S. & Randall, D.J. (eds) Fish Physiology. Academic Press, 5:79-120.

Hardenburg, J. D. F. 1936. On a collectin of fishes from the estuary and the lower and middle course of the River Kapuas (West Borneo). Treubia 15(3):1-14.

Harrington, R. W. 1955. The osteocranium of the American cyprinid fish *Notropis bifrenatus* with an annoted synonymy of teleost skull bones. *Copeia*. 1955:267-290.

Heckel, J. J. 1843. Abbildungen and Beschreibungen der Fische Syriens In. *Russegger's Reisen in Europe, Asien, and Africa*. Stuttgard. 1(2):1-109.

Henning, N. 1950. *Grundzuge einer Theorie der Phylogenetschen Systematik*. Deutscher Zentraverlag, Berlin. 370pp.

-----. 1966. *Phylogenetic Systemaics*. University of Illinois Press, Urbana, Illinois:263 pp.

Hensel, K. 1970. Review of the classification and of the opinion on the evolution of Cyprinoidei (Eventognathi) with an annotated list of genera and subgenera described since 1921. *Annot. Zool. Bot. Bratislava*. 1970(57):1-45.

Herre, A. W. C. T. and G. S. Myers. 1937. A contribution to the ichthyology of the Malay Peninsula. *Ruffles Mus. Bull.* 13:6-75.

Hoda, B. W. E. and H. Tsukahara. 1971. Studies on the development and relative growth in the carp, *Cyprinus carpio* (linne.). *J. Fac. Agric. Kyuchu Univ.* 16(4):388-509.

Hora, S. L. 1921. Indian cyprinid fishes belonging to the genus *Garra*, with notes on related species from other countries. *Rec. Indian Mus.* 22(5):634-687.

-----. 1922. Structural modification in the fish of mountain torrents. *Rec. Indian Mus.* 24:31-61.

-----. 1940. The game fishes of India. *J. Bombay Nat. Hist. Soc.* 41(3):518-525.

-----. 1942. Notes on fishes in the Indian Museum. XLII. On the systematic position of the Indian species of *Scaphiodon* Heckel. *Rec. Indian Mus.* 44(1):1-14.

Hora, S. L. and D. D. Mukerji. 1934. Notes on fishes *Rec. Indian Mus.* 36:359-362.

-----. 1936. Fish of the eastern doons, united provinces. *Rec. Indian Mus.* 38:133-146.

Hora, S. L. and K. S. Nisra. 1942. Fish of Poona, Part II. *J. Bombay Nat. Hist. Soc.* 43(1):225.

Howes, G. J. 1978. The anatomy and realtionships of the cyprinid fish *Luchiobrama macrocephalus* (Lacepede). *Bull. Br. Mus. Nat. Hist.*(Zool.) 34(1):1-64.

-----, 1980. The anatomy, phylogeny and classification of bariliine cyprinid fishes. *Bull. Br. Mus. Nat. Hist. (Zool.)* 37(3):129-198.

Hubbs, C. L. and K. F. Lagler. 1958. *Fishes of the great Lakes region* Michigan Univ. Press. 213pp.

Hubendick, B. 1942. Zur Kenntnis der Entwicklung des primodial-craniums bei *Leuciscus rutilus*. *Arkiv. Zool. (Stockholm)*. 34(7):1-35.

Inger, R. F. and Chin P. K. 1962. The fresh-water fishes of North Borneo. *Fieldiana (Zoology)*. 45: 268 pp.

Jara, z. 1957. On the morphology and function of the so-call palatal organ in carp (*Cyprinus carpio*). Przegl. Zool. 1(1): 176-178.

-----. 1963. On some consequences of the adaptation of fishes to the aquatic mode of life. Przegl. Zool. 7(3): 207-218.

Jeward, L. A. J. 1975. Biometric Studies on Three *Barbus* Species from Basrah Water, Basrah, Iraq. Al. Khalij Al-Arabi. 3:247.

Jones, S. 1941. Larval Development of *Garra Ceylonensis ceylonensis* (Bleeker). Rec. Indian Mus. 43(2):117-120.

Jordan, D. S. 1919. The Genera of Fishes. Stanforn University Press. Part 2: 163-284.

Jubb, R. A. 1966. Note on the Popular Angling Yellowfishes and Distribution Outside Their Native Ranges, Piscator. 68:123-124.

Kafuku, T. 1958. Speciation in cyprinid fishes on the basis of intestinal differentiation, with some references to that among catostomids. Bull. Freshwat. Fish. Res. Lab. Tokyo. 8(1): 45-78.

Kamal, Y. 1964. Food Consumed and Differentiation of the Alimentary Canal and Associated Structures in *Catla Catla* (Ham.), Indian J. Fish (A)11 (1) : 449-464.

Kapoor, B. G. 1956. Oral Valve of Teleosts. Jap. J. Ichthyol. 5:127-131.

--------, 1964. Gill Rakers in a Few Indian Freshwater Fish. Annali Mus. Civ. Stor. Mat. Giacomo Doria. 75:126-143.

Kapoor, B. G. and N. E. Evans. 1975. The Gustatory System in Fish, Adv. Mar. Biol. 13:53-108.

Kapoor, B. G., H. Smit and I. A. Verighina. 1975. The Alimentary Canal and Digestion in Teleosts Adv. Mar. Biol. 13:109-239.

Kappers, L. U., C. C. Nuber and E. C. Crosby. 1960. The Comparrative Anatomy of the Nervous System of Vertebrates Including Man. Hafner, New York (3 Vol.)

Keast, A. 1968. Evolution of mammals on the southern continents. IV. Australian mammals: Zoogeography and evolution. Quart. Rev. Biol. 43(4): 373-408.

Khanna, S. S. and N.R. Mehrotra. 1970. History of the Buccopharynx in Relation to Feeding Habits in Teleosts, Proc. Natn. Acad. Sci. India (B). 40 (3):61-80.

Khanna, S. S. and B. K. Singh. 1966. Morphology of the Teleostean Brain in Relation to Feeding Habits. Pro. Natn. Acad. Sci. India. (B). 36(3):306-316.

Kilarski, W. and J. Bigaj. 1971. The Fine Structure of Striated Muscle Fibres of Tunica Muscularis of the Intestine in Some Teleosts, Z. Zellforsch. Mikrosk. Anat. 113: 472-489.

King, R. E. 1975. The Morphology of the Buccal Cavity of the Goldfish, *Carasius auratus*, S. Afri. J. Sci. 71:179-183

Kliewer, E. V. 1970. Gill Raker Variation and Diet in Lake White Fish *Coregonus Clupeaformis*, in Northern Manitoba, In: Biology of Coregonid Fishes (Linsey, C.C. & C.S. Woods, eds):147-165.

Kobayashi, N. and T. Malda. 1962. On the Pharyngeal Bones and Their Teeth in Japanese Leucisciene and Cyprinine Fishes, Cyprinidae, Zool. Mag. Tokyo, 71:307.

Kramer, D. L. 1973a. Identification and Morphology of Fish of the Genus *Labeo* From the Volta Lake and Its Tributaries, V.B.R.P. Tech. Rep., 10 (37):1-11.

-----. 1973b. Preliminary Investigation into the Biology of *Labeo* in the Volta Lake, V.B.R.P. Tech. Rep. 10(38):1-24.

Krawarik, F. and K. Suss. 1936. Nerven and Nervendigungen in der Schleimha ut des Karpfenrussels, Z. Mikrosk.-Anat. Forsch. 39:379-393.

Lal, N. B., A. N., Bhatnagar & S. Oberoi. 1964. Bucco-Pharyngeal Regian of *Labeo Dero* (Hamilton). Proc. Natn. Acad. Sci. India. (B). 34:419-421.

Lowe-McConnel, R. H. 1969. Specification in Tropical Fresh Water Fishes, Biol. J. Linn. Soc., 1(1&2):51-75.

-----. 1975. Fish comunities in tropical freshwater. Longman, London. 337 pp.

Lukowicz, M. Von, 1966, Uber Die Barteln and Dier Lippenepidermis Verschiedener Agyptischer Sub Wasserfische Mit Einigen Versuchen Zum Geschmackssinn, Zool. Anz. 176(6):396-413.

Macann, T. T. 1974. Freshwater Ecology. Longman, London (2 ed.):343 pp.

Majumdar, N. N. 1952. On the Anatomy and Histology of the Palate of *Cirrhina Mrigala* (Ham.) with Special Reference to Papillae Present on it together with Comments on their Possible Respiratory Function, J. Zool. Soc. India, 3(2):255-265.

Majumdar, N. N. and B. P. Saxena. 1961. On the Palatal Organs of *Labeo Dero* , Proc. Natn. Acd. Sci. India. (B), 31(1):109-116.

Manning, F. B. 1923. Hearing in Goldfish in Relation to the Structure of the Ear, J. Exper. Zool. 41(1):5-20.

Mathias, P. 1920. Sur La Structure Des Levres Des Poissons Du Genre *Chondrostoma* (famille des cyprinidae), C.R. Hebd Seances Acad. Sci. Paris , 170:1464-1466.

Matthes, H. 1963. A Comparative Study of the Feeding Mechanisms of Some African Cyprinidae (Pisces, Cyprinidfomes), Bijdr. Dierk., 33:1-35.

Mayr, E. 1965a. Numerical Phenetics and Taxonomic Theory, Syst. Zool., 14:73-97.

-----. 1965b. Classification and Phylogeny Amer. Zool., 5:165-174.

-----. 1969. Principles of Systematic Zoology, McGraw-Hill Book Co., New York, 428p.

-----. 1974. Cladistic Analysis or Cladistic Classification? Z. f. Zool. Systematik U. Evolutionsforschung, 12:94-128.

McClelland, J. 1839. Indian Cyprinidae. Asoatic Reseahches. 19(2): 217-471.

Miakowski, M. 1960. Variabilitatsstudien an Den Halswirbeln, dem Weberschen Apparat Und dem Schlundgebib von Cypriniden, Arch. Fisch. Wiss., 11:119-141.

Miles, R. S. and G. C. Young. 1977. Placoderm interrelationships reconsidered in the light of new ptyctodontids from Gogo, Western Australia. In: Problebs in Vertebrates evolution. Mahala Andrews, S., R. S. Miles, and A. D. Walker (eds.). Linn. Soc. Symp. (4):123-198.

Minzenmay, A. 1933. Die Mundregion der Cypriniden, Zool. Jb., 57 (2):191-286.

Mitchell, E. G. 1904. Oral Breathing Valves of Teleosts, Their Modifications and Relation to the Shape of the Mouth, Am. Nat. 38(446):153-164.

Moitra, S. K. and G. M. Sinha. 1972. The Structure, Distribution and Probable Function of Taste Buds and Nucus Cells in the Alimentary Tract during the Life History of *cirrhinus mrigala* (Hamilton), J. Inld. Fish. Soc. India., 4:103-114.

Molengraaf, G. A. 1921. Modern deep sea research in the East-Indian Archipelago. Geogs. Jour. 57: 95-121.

-----. 1929. The coral reefs in the East-Indian Archipelago, their distribution and mode of development. Proc. Pan-Pacific Sci. Congress. Java. 2A: 55-89.

Moodie, R. L. 1922. The Influence of the Lateral Line System of the Peripheral Osseus Elements of Fishes and Amphibia, J. Comp. Neurolog., 34:319-351.

Mookerjee, H. K. 1945. Life History of Some Major Carps of Bengal, Sci. Cult. 10(9):400.

Moriarty, D. J. W., J. Darlington, I. G. Dunn, C. M. Moriaty, and M. P. Tevlin. 1973. Feeding and Grazing in Lake George, Uganda, Proc. R. Soc., (B) 184:299-319.

Mukerji, D. D. 1932. On a Small Collection of Fish from the Bhavani River (S. India), J. Bombay Nat. Hist. Soc., 35 (1-2):162-171.

Myers, G. S. 1960. Preface to any Future Classification of the Cyprinid Fishes of the Genus *Barbus*, Stanford Ichthyol. Bull. 7 (4):212-215.

Nelson, E. M. 1949. The Opercular Series of the Catastomidae, J. Morph. , 85:559-568.

Nelson, G. J. 1969. Gill Arches and the Phylogeny of Fishes, with Notes on the Classification of Vertebrates, Bull. Amer. Mus. Nat. Hist. 141(4):477-552.

Nichols, J. T. 1943. The Fresh-Water Fishes of China, Amer. Mus. Nat. Hist. Nat. Hist. Central Asia. 9:1-322.

Nichols, J. T. and C. H. Pope. 1927. Thew Fishes of Hainan, Bull. Amer. Mus. Nat. Hist. 54:321-394.

Nikolsky, G. V. 1954. Special Ichthyology (translated from from Russian, 1961). U. S. Department of Commerce. 538pp.

Okada, Y and S. S. Kubota. 1956. Studies on the Taste Buds Found in Oral Cavity of *Carasius auratus* L. Zool. Mag. Tokyo. 65(9):347-351.

Patterson, C. 1977. The Contribution of Paleontology to Teleostean Phylogeny, In:M.K. Hecht, P.C. Goody & B.M. Hecht (eds), Major Patterns in Vertebrate Evaluation:579-643.

Patterson, C. and D. E. Rosen. 1977. Review of Ichthyodectiform and other Mesozoic

Teleost Fishes and the Theory and Practice of Classifying Fossils, Bull. Am. Mus. Nat. Hist. 158(7):81-172.

Pictet, A. 1909a. L'Histologies de la Mugueuse Baccale et Intestinale des Poissons Cyprinoides, C.R. Seances Soc. Phys. Hist. Nat. Neneve, 26:35-38.

-----. 1909b. Contribvution a l'etude Histologigue du Tube Digestif des Poissons Cyprinoides. Revue Suisse Zool., 17:1-76.

Ping, C., S. Pao, and J. S. Chen. 1959. A Preliminary Observation on the Gross Anatomy of the Nervous System of the Carp (*Cyprinus carpio*), Acta Zool. Sinica (3):320-329.

Popta, C. M. L. 1904-1905. Suite des Descriptions Preliminaires des Nouvelles Especes de Poissons Recueilles au Borneo Central par M. le Dr. A.W. Nieuwenhuis en 1898 et en 1900. Notes Leyden Mus. 25:171-176.

-----. 1906. Poissons de Borneo Central, Note 1, Resultats Ichthyologiques des Voyages Scientifiques de Monsieur le Professeur Dr. A.W. Nieuwenhius dans le Centre de Borneo (1898 et 1900), Notes Leyden Mus. 27:1-304.

Poromeswaren, G., C. Selvaraj, and S. Radhakrishnan. 1974. Observations on the Biology of *Labeo Gonius* (Hamilton), Indian J. Fish. 71(1):54-75.

Raffin-Peyloz, R. 1955. Etude Histologique des Barbillons de Quelques Poissons d'eau Douce. Trav. Lab. Hydrobiol. Piscic. Uinv. Grenoble. 47:73-97.

Ramasawami, L. S. 1952. Skeleton of Cyprinid Fishes in Relation to Phylogenetic Studies, 1. The Systematic Position of the Genus *Gyrinocheilus* Vaillant, 2. The Systematic Position of *Psilorhynchus* McClelland, Proc. Natn. Inst. Sci. India 18(2):125-150.

-----. 1955. The Skeleton of Cyprinoid Fishes in Relation to Phylogenetic Studies, The Skull and Weberian Apparatus of Cyprininae (cyprinidae), Acta Zoologica 36:199-242.

Rauther, M. 1928. Der Saugmund von *Discognathus*, Zool. Jb., (3) 45:45-76.

Regan, C. T. 1911. The Classification of the Teleostean Fishes of the Order Ostariophysi, I. Cyprinoidea, Ann. Mag. Nat. Hist. 8(8):13-32.

Reid, G. M. 1978. A Systematic Study of Labeine Cyprinid Fishes with Particular Reference to the Comparative Morphology, Functional Morphology and Morphometrics of African *Labeo* Species, Ph.D. Thesis, Queen Elizabeth College, London University. 770pp.

Ridd, M. F. 1971. South-East Asia as a Part of Gondwanaland, Nature. London. 230:531-533.

Ross, H. H. 1974. Biological Systematics. Addison-Wesley Publ. Co. Inc. 345pp.

Sagemehl, M. 1891. Beitrage Zur Vergleichenden Anatomie der Fishe, IV Das Cranium der Cyprinoiden, Morph. Jahrb. 17:489-595.

Sanders, M. 1934. Die Fossilen Fishe der Alttertiaren Susswasserablagerungen aus Mittel-Sumatra. 143pp., pls. 1-9.

Sarbahi, S. 1932. The endoskeleton of *Labeo rohita* (Ham. Buch.), J. Proc. Asiat. Soc.

Bengal (N.S.). 28(1): 295-347.

-----. 1939. The Alimentary Canal of *Labeo rohita* (Hamilton), J. Asiat. Soc. Bengal (3). 5(2): 87-116.

Sato, N. 1937. Histological Observations on the Barbels of Fishes. Sci. Rep. Tohoku Univ. (4)12: 165-276.

Sauvage, H. E. 1878a. Note sur Quelques Cyprinidae et Cobitidinae d'especes inedites provenant des eaux douces de la Chine, Bull. Soci. Philo Paris Serie 7). 2: 86-90.

-----. 1878b. Note sur Quelques poissons d'especes nouvelles provenant des eaux douces de l'Indo-chine. Boll. Soc. Philom. Paris. Series 7, 2: 233-242.

-----. 1881. Recherches Sur la Faune Ichthylogique de l'Asie et Description d'especes Nouvelles de l'Indo-Chine, Nouv. Arch. Mus. Hist. Nat. Paris (Serie 2). 4: 123-194.

-----. 1883. Sur une collection de poissons recueillie dans le Me-Nam (Siam) par M. Hammand. Bull. Soc. Philom. Paris. Ser. 7. 7:150-155.

Saxena, D. B. 1959. Oral Breathing Valves in Some Freshwater Teleost Skeleton, Ichthyologica. Kanpur 1:15-26.

-----. 1965. Osteology of the Freshwater Teleost *Catla Catla* (Ham.) Part I. Osteocranium, Vest. Cal. Spol. Zool. 29:146-155.

Saxena, P. K. 1966. The head skeleton of the Indian carp *Cirrhina mrigala* (Ham). Zool. Anz. 176(5): 366-379.

Saxena, S. C. 1960. The Cranial Musculature of a Hill-Stream Cyprinid Fish *Garra Mullya* (Sykes). Proc. Natn. Inst. Sci. India. (B). 26:176-188.

Schoonbee, H. J. 1969. Notes on the Food Habits of Fish in Lake Baberapan, Western Transvaal, South Africa, Verh. Inter. Verein. Theor. Angew. Limnol. 17:689-781.

Sehgal, P. 1966. a. Food and Feeding Habits of *Labeo Calbasu* (Hamilton), b. Anatomy and Histology of the Aliimentary Canal of *Labeo Calbasu* (Hamilton), Res. Bull. Punjab Univ. Sci. 17(3-4):251-256, 257-266.

Sehgal, P. and J. Salaria. 1970. Functional Anatomy and Histology of the Digestive Organs of *Cirrhina mrigala* (Cuv. & Val.), Proc. Natn. Acad. Sci. India (B). 40:212-222.

Shiraishi, Y. and S. Kimura. 1971. Distribution of fishes and environment condition in artificial lake in Thailand. Bull. Freshwater Fish. Res. Lab. Tokyo. 21(1): 47-58.

Sidthimunka, A and M. Potaros. 1968. Observation of the hydrology and fisheries of Ubolratana Reservoir (1965-66). Indo-Pacific Fisheries Council. FAO Regional office for Asia and Far East. Bangkok. Thailand. Occasional Paper. 69/3: 18pp.

Sinha, G. M. & S. K. Moitra. 1975. Functional Morpho-Histology of the Alimentary Canal of an Indian Freshwater Major Carp *Labeo rohita* (Hamilton) during Its Different Life History Stage, Anat. Anz. 138:222-239.

Sneath, P. H. and R. R. Sokal. 1973. Numerical Taxonomy. Freeman & Co., San Francisco:573pp.

Smith, H. M. 1945. Fresh-Water Fishes of Siam or Thailand, Bull. U.S. Natn. Mus. 188:1-621.

Soresco, C. 1971. Development de Quelques os du Neurocrane Chez *Cyprinus carpio* L. Anat. Anz. 128: 16-38.

Sorescu, C. 1970. Etude Comparative du Crane de Quelques Cyprins en Relation Avec Leur Phylogenie (sous-familles des Danioninae, Barbinae, Cyprininae), Rev. Roum. Biol. (Zool.), 15(4):239-245.

Stauffer, P. H. 1974. Malaya and Southeast Asia in the Pattern of Continental Drift, Bull. Geol. Soc. Malaysia, 7:89-138.

Steindachner, F. 1870. Zur Fischfauna des Senegal, Sber Akad. Wiss. Wien (I). 61:562.

Svardson, G. 1970 Significance of Introgression in Coregonid Evolution, In:Biology of Coregonid Fishes (Lindsay, C.C. & C.S. Wood, eds), pp.

Tanaka, M. 1971. Studies on the Structure and Function of the Digestive System in Teleost Larvae-3. Development of the Digestive System during postlarval stage, Jap. J. Ichthyol. 18:64-174.

Taylor, W. R. 1967. An Enzyme Method of Clearing and Staining Small Vertebrates. Proc. U.S. Nat. Mus. 122(3596):1-17.

Tandon, K. K. and S. Arora. 1970. Morphology of *Labeo dero* (Ham.) Res. Bull. Punjab Univ. (Sci.). 21:243-245.

Teodorescu-Balteanu, A. C. 1971. Contribution a l'etude de la Veriabilite Morphologique de la Gavite Bucco-Pharyngienne Chex Cyprinidae, Studii Corc. Biol. (Ser. Zool.). 23:433-438.

Tirant, G. 1929. Notes sur les Poissons de la Bassecochinchine et du Cambodge, Excursions et Reconnaissances 9(1885):413-438, and 10(1885):91-198, Reprinted 1929, with new pagination (43-163) as part of series of papers under title "Oeuvre Ichthyologique de G. Tirant," Service Occeanographique des Peches de l'Indo Chine, Saigon, by Pierre Chevey.

Tretiakov, D. K. 1946. Systematic Groups of Cyprinidae, Zool. Zh. 25:149-156.

Vandewalle, P. 1975. On the Anatomy and Function of the Head Region in *Gobio gobio* (L) (Pisces, Cyprinidae), 3. Bones Muscles and Ligaments. Forma Functio. 8:331-360.

Vasilevskaya, N. E. and I. D. Pavlov. 1971. Electrical Reaction in Fish Brain to Stimulation of Oral Cavity Chemoreceptors, Zh. Evol. Biokhim. Fiziol. 7:280-286.

Verigina, I. A. 1969. Structure of the Digestive Tract of the Lake Sevan Khramulya (Cyprinidae, *Varicorhinus capoeta sevagni* (F.)), Probl. Ichthyolo. 9(3):428-433.

Von Lukowicz, M. 1966. (see Lukowicz, M. Von.)

Weber, M. and L. F. de Beaufort. 1916. The Fishes of the Indo-Australian Archipelago, Ostariophysi: Cyprinoidea, 455 pp.

Wunder, W. 1971. Histological Research Work on the Mucous Membrane in the Gut of the Carp (*cyprinus carpio* L.), Biol. Zbl. 90: 205-216.